Columbia River Project Water Use Plan

Duncan Reservoir Riparian Vegetation Monitoring

Implementation Year 4

Reference: DDMMON#8-2

Duncan Reservoir Riparian Vegetation Monitoring Year 4 Final Report

Study Period: April 2018 – January 2019

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DDMMON#8-2 Duncan Reservoir Riparian Vegetation:
Analyses of Vegetation Dynamics from 2009 to 2018, Accompanying a Change in Reservoir Regime

Final Report

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Cover photo

Site 13 A downward view of part of the alluvial fan at Puddlingbowl Creek near the northern (upstream) end of Duncan Reservoir (July 30, 2018, photo by Stewart Rood). All ground level photos by Mary Louise Polzin, VAST Resource Solutions unless otherwise noted.

Executive Summary

A ten-year vegetation monitoring study of the drawdown zone of Duncan Reservoir was undertaken from 2009 to 2018 as part of the implementation of the Duncan Dam Project Water Use Plan (WUP). Commencing in 2008, the WUP Alternative S73 (Alt S73) for Duncan Dam operation changed the reservoir fill to reach full pool (576.7 m) between August 1 and 10. The reservoir level then decreased to 575.5 m and was maintained within 0.3 m of this level until September 5. The Pre-Alt S73 regime was slightly lower, and the reservoir reached an average fill level of 575.8 m by July 29 and varied within 3.8 m of this level to August 18. Prior to implementation, the WUP hypothesized that the Alt S73 regime could result in an ecological trade-off, with a promotion of riparian vegetation along the Lower Duncan River below Duncan Dam versus a decrease in riparian vegetation in the drawdown zone of Duncan Reservoir, due to the increased inundation elevation and duration.

Subsequently, this study evaluated the impacts from the implementation of Alt S73 on riparian vegetation in the reservoir drawdown zone. The study assessed the hypothesized vegetation decrease, and provided guidance for reservoir management, through improved understanding of the relationships between reservoir regime, physical environmental conditions and characteristics of the different riparian plant species.

To address the management questions and hypotheses about changes within the riparian habitat communities, vegetation community dynamics were monitored at twelve sites around Duncan Reservoir; these were primarily on alluvial fans (outflow deltas) from tributary creeks. The vegetation communities at these sites were assessed with interpretation of orthorectified colour aerial photographs, taken at three-year intervals. Complementary field inventory assessed vegetation in 600 to 2,000 quadrats along 30 belt transects that extended from the full pool shoreline down to depths of 10 m into the drawdown zone. These transects were similarly revisited at the three-year intervals, including 2009, 2012, 2015, and 2018.

Change-detection mapping revealed a reduction in reservoir vegetation over the study interval, especially from 2009 to 2012, and gradually to 2018. The sparsely vegetated area decreased while the area of barren ground correspondingly increased four-fold (15.7 per cent of the total sampling area in 2009 versus 61.2 percent in 2018). Reciprocally, the overall vegetated area decreased by about one-half (85.4 per cent in 2009 to 39.9 per cent in 2018). This reduction primarily occurred in the lower drawdown zones, 4 to 8 m elevation below full pool, where sparsely vegetated bands become more barren. There was generally slight change in the zones of perennial vegetation and woody vegetation, primarily willow shrubs, which were restricted to the upper 2 m below the full pool shoreline. In that upper band, there were sparse saplings of the predominant regional riparian tree, black cottonwood, *Populus trichocarpa*, in 2009 but very few saplings thereafter, indicating the lack of cottonwood colonization with the Alt S73 reservoir regime.

The decrease in vegetation in the drawdown zones was associated with increased inundation duration with the Alt S73 reservoir regime. Along with inundation, the vegetation distribution and abundance were also influenced by environmental conditions, being favored by finer substrate texture (sands and small gravels) and flatter slope. The weather within and across years would also influence plant colonization and growth. Large woody debris was floated to the shorelines with the reservoir rise, covering and scouring prospective vegetation bands, and contributing to the decrease in juvenile woody vegetation (0.5 m to 2 m tall) within the upper metre of elevation below full pool.

Species richness, the number of plant species, was highest near the full pool shoreline and decreased as elevation decreased and inundation duration increased. Richness varied substantially across the reservoir sites and was proportionally consistent across those sites over the study interval from 2009 to 2018. The primitive plant horsetail (*Equisetum spp*.) was the most common plant in the drawdown zones and was prolific at the gradually sloped site near the delta formed by the Duncan River inflow. The second most abundant plant species, *Carex utriculata* (beaked sedge), declined after 2009 and this wetland graminoid may be a diagnostic indicator to assess the effect of reservoir regulation on riparian vegetation.

These analyses revealed that riparian vegetation was generally sparse in the drawdown zone of Duncan Reservoir and was further decreased with a revised regime that increased the frequency and duration of inundation of the upper drawdown zone. The study also provides information on the important environmental factors including elevation, substrate texture and slope, as well as the varying inundation tolerances versus exposure requirements for the different native plant species as well as for disfavoured plants such as invasive weeds. The findings will be instructive for developing dam operational regimes that could benefit riparian vegetation communities and ecosystems, as well as increasing survival for transplanting or seeding projects for reservoir enhancement. In particular, reducing the frequency and duration of flooding of the upper band could allow perennial vegetation, including riparian shrubs, to expand in that upper area of the reservoir drawdown zone. This might enhance riparian vegetation especially on the alluvial fans of inflowing creeks, and on the aggrading delta from the inflow of the upper Duncan River into the Duncan Reservoir.

KEYWORDS Duncan Dam, Duncan Reservoir, Drawdown Zone, Inundation Tolerance, Riparian Vegetation

Management Question	Final Study Year 4 (2018)
1) Will the implementation of DDM WUP result in neutral, positive, or negative changes to riparian vegetation communities within the drawdown zone for the Duncan Reservoir?	The analyses of aerial photographs from 2009, 2012, 2015 and 2018, with vegetation mapping based on field assessment, revealed a progressive decrease in the area of sparse vegetation within the sampled areas of the reservoir drawdown zone. Conversely, over the decade, there were equivalent increases in the areas that were barren, and this indicated a widespread transition from sparse vegetation to barren. This change was partly due to the change in the seasonal pattern of the reservoir level, which accompanied Alt S73. These findings oppose the null hypothesis, H_{01}, and indicate that Alt S73 resulted in decreases in the areas of vegetation communities within the Duncan Reservoir drawdown zone. This finding is consistent with the prediction that accompanied the Water Use Planning (WUP) process that led to the selection of Alt S73 for implementation with the Duncan Dam operation. Repetitive field inventories of 600 to 2,000 quadrats in the Duncan Reservoir drawdown zones in 2009, 2012, 2015 and 2018 revealed declines in occurrences and especially abundances of various riparian plants. Multivariate modeling revealed that the vegetation cover (abundance) was positively associated with the exposure interval, which is the inverse of the duration of inundation from reservoir flooding. This opposes H_{02} and indicates that extended shoot and root-zone flooding impeded riparian vegetation. This provides an ecophysiological mechanism that underlies the decline in riparian vegetation in the Duncan Reservoir drawdown zone that followed from the implementation of Alt S73.

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1.0 Introduction

1.1 Project Overview

This report summarizes the fourth and final field season (Study Year 4, 2018) of the 10-year riparian vegetation monitoring study for the Duncan Reservoir drawdown zone (DDMMON#8-2). Hypotheses testing and the management questions are assessed in this final report.

Prior to the Duncan Dam, the original Duncan Lake was 25 km long and outflow from that lake to the lower reach of the Duncan River commenced approximately 4 km upstream from the current dam location. The original location of the community of Houser was at the downstream end of Duncan Lake and was moved to higher ground due to the subsequent flooding and enlargement of Duncan Lake, which created the Duncan Lake Reservoir (Figure 1-1). This reservoir is sometimes referred to as Duncan Lake but since the natural lake represents less than one-half of the reservoir area, we will refer to the impoundment as the Duncan Reservoir. Zones flooded with the Duncan Reservoir, included riparian floodplains (1), wetland complexes (2), and multiple channels and riparian complexes with inflows of Howser (3) and Glacier Creeks (4) (Figure 1-1) (Utzig and Schmidt 2011).

The Duncan Reservoir extends northward from the Duncan Dam, which was constructed 11 km north of Kootenay Lake, in the central Columbia Mountains of southeastern British Columbia (Figure 1-2). The Duncan Reservoir is 45 km long, averages 1.5 km in width, and is fed by a rugged, high-elevation drainage area of 2,010 km^2 (Miles 2002). Both the Kootenay Lake and the Duncan Reservoir are situated in the Purcell Trench, which was formed by a geologic fault that somewhat parallels the Continental Divide. The Purcell Trench was scoured by glaciers to form the steep-walled, U-shaped valley that contains these two water bodies (Figure 1-2).

Operational changes were recommended in 2005 by BC Hydro's Duncan Dam Water Use Plan Consultative Committee Report (DD WUP CC). This was part of a larger process for the lower Duncan River and Duncan Reservoir to address environmental and social issues (BC Hydro 2005). The recommended new operating Alternative S73 (Alt S73) regime (fill and drawdown level control) has been implemented since January 2008 under the Water Act Order for Duncan. Alt S73 regime has the reservoir reaching full pool (576.7 m) between August 1 and August 10, and then levels decrease to 575.5 m and are maintained within 0.3 m of this level until September 5th (BC Hydro 2009).

Alt S73 was expected to have a negative impact on the wildlife habitat along the Duncan Reservoir as a result of decreasing vegetation distribution and abundance (cover) (BC Hydro 2005). To test this prediction, a longer-term wetland, and riparian vegetation-monitoring program was recommended by the DDM WUP CC to assess Alt S73. This would involve analyses of riparian vegetation distribution and abundance (cover) and testing of hypotheses underlying the Water Use Plan (WUP).

This study was designed to sample and analyze the conditions of vegetation communities triennially for 10 years and thus to track changes in vegetation distribution and cover following the implementation of Alt S73. The study involved repetitive vegetation surveys in 2009, 2012, 2015 and 2018, thus providing a 10-year monitoring and assessment project.

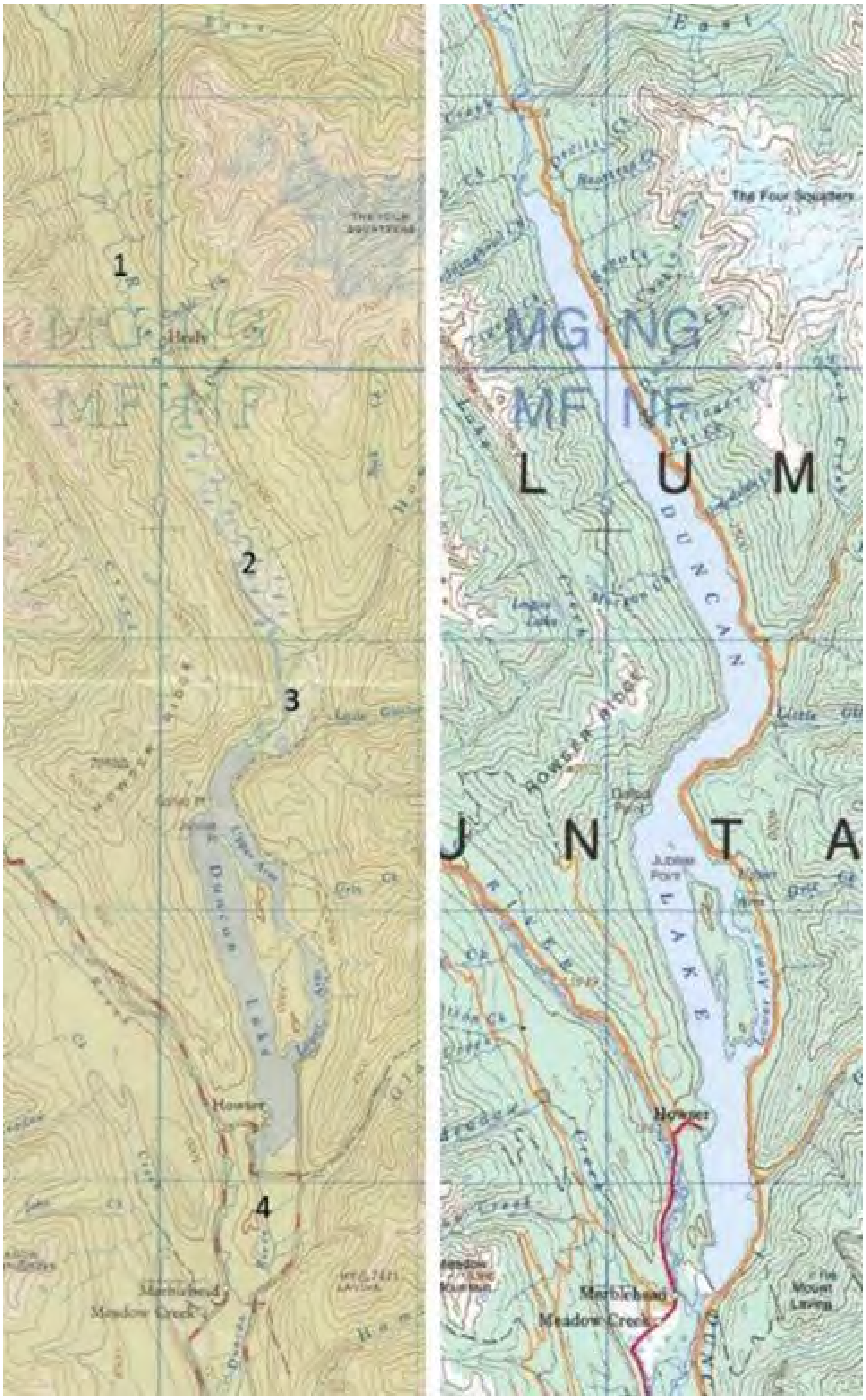


Figure 1-1: **The area with Duncan Lake and subsequently Duncan Reservoir displayed in 82K Lardeau, 1:250K Canadian federal topographic maps from 1959 (left, based on aerial photographs from 1953) and 1992 (right, aerial photographs from 1977, with updates based on 1987 satellite imagery).**

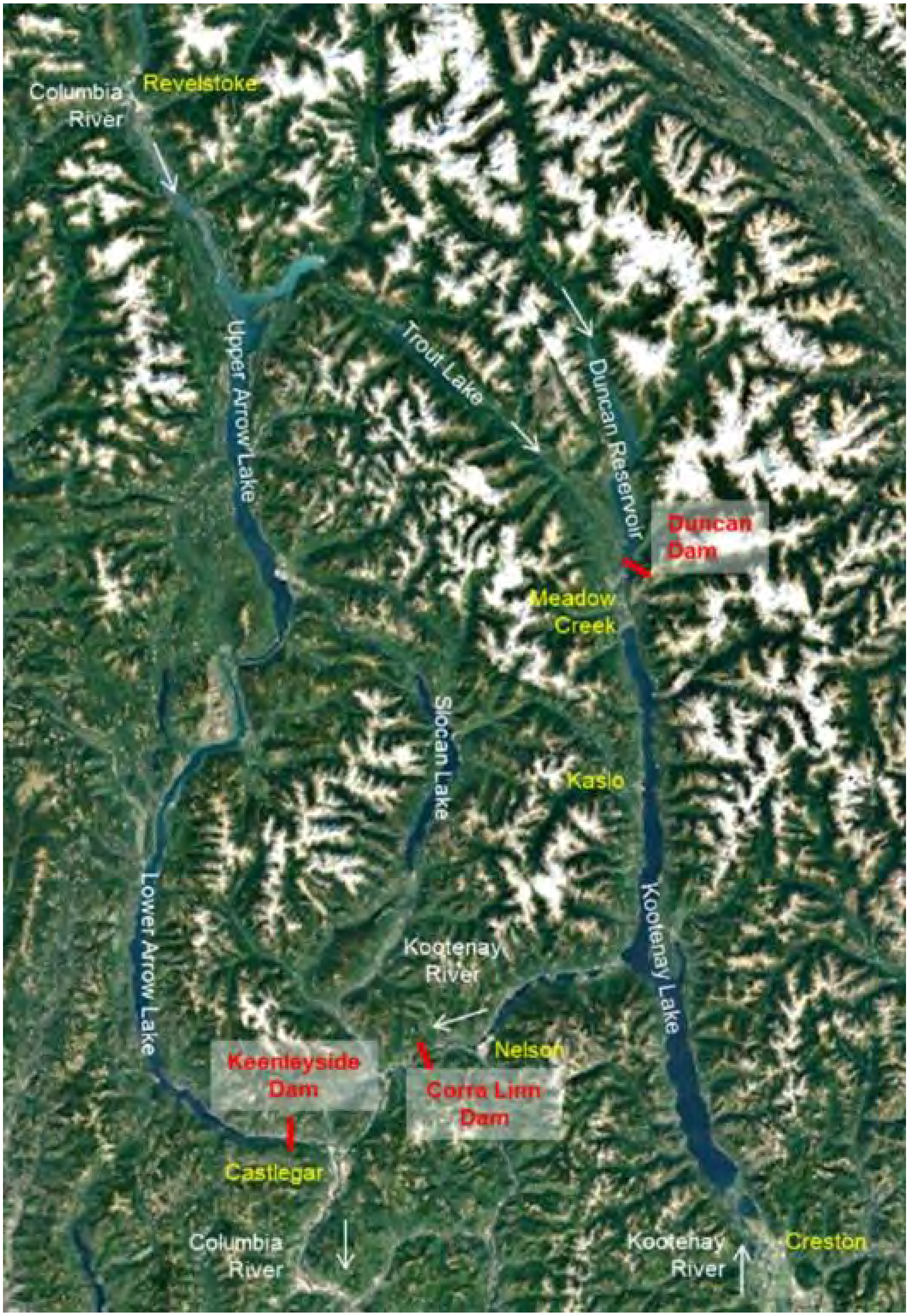


Figure 1-2: **A composite Landsat image with reservoirs and lakes of the West Kootenay region in southeastern British Columbia, including the Duncan Reservoir (Google Earth). Duncan and Keenleyside Dams were constructed following the Columbia River Treaty and the older Corra Linn Dam slightly elevates Kootenay Lake; arrows indicate river flow directions**.

1.2 Background

Data from storage reservoirs world-wide indicate that reservoir drawdown zones impose physically stressful environments for vegetation (Nilsson and Keddy 1988 and Hill et al. 1998). Drawdown or storage reservoirs are very common worldwide and are managed to retain flows during certain intervals with subsequent controlled release of the stored water. These reservoirs provide strategies to reduce downstream flooding; enable hydroelectric power generation; provide off-stream water for agricultural, urban and industrial uses; and enable environmental in-stream flows for aquatic or riparian ecosystems and various other applications.

Accompanying the manipulation of seasonal river flows and water supplies, there are periodic filling and drawdown of the storage reservoir pools. When full, reservoir banks are completely inundated, while during the drawdown, those same zones become fully exposed. Aquatic plants are able to withstand inundation but are unable to survive in dry conditions. Conversely, terrestrial plants are generally intolerant of complete inundation, particularly when such inundation lasts for days, weeks, or months.

Wetland and riparian plants are better able to withstand cycles of inundation, but these same plants are generally drought-intolerant. Thus, there is a general trade-off relative to the capacity of plants to survive in very wet *versus* very dry environments. Consequently, few if any plants are able to survive in reservoir drawdown zones, and these areas are typically almost barren of vegetation (Nilsson et al. 1997, Jansson et al. 2000). The exceptions generally involve ruderal annuals, which are species that rapidly colonize disturbed areas, since they are able to complete their life cycle within the limited drawdown interval (Braatne et al. 2003). Seedlings or occasionally clonal propagules of these plants establish in the newly exposed moist reservoir shorelines and the successful plants are able to quickly grow and reproduce, producing seeds prior to the subsequent inundation. The ruderal annuals are commonly weedy plants that establish quickly and often have prolific reproductive potential. Such plants are often alien species that have typically been unintentionally introduced into a region and their prolific reproductive capacities may allow them to colonize areas characterized by disturbance or abrupt physical change, as is present in reservoir drawdown zones.

Despite the global abundance of drawdown reservoirs, there have been far fewer scientific studies of associated vegetation than has been the case for many other environments, such as wetland and riparian zones (Hill et al. 1998). Many of the same physical factors likely underlie vegetation establishment, survival and expansion in reservoirs, wetlands and riparian zones (Jansson et al. 2000), and the distinctive and severe reservoir environments provide opportunities for scientific study (Nilsson and Keddy 1988, Braatne et al. 2008). Since these zones are relatively impoverished, there are fewer species to investigate and fewer interspecific interactions, such as competition. Since the zones are dominated by ruderal annuals, the process of colonization is critical and may yield useful information about the life history components of the associated plants, as well as insight into the fundamental nature of weedy and invasive plants.

Distribution patterns predicted prior to baseline data analyses were found to be generally accurate (Polzin et al. 2010) and some factors became better understood as the project progressed and more data were collected.

1.3 Project Objectives and Scope

The specific program objectives are (BC Hydro 2009):

- To map the distribution of wetland and riparian vegetation within the drawdown zone of Duncan Reservoir using aerial photography, every third year starting in 2009;
- To monitor changes over time in the area coverage and plant species composition of vegetated communities within the drawdown zone of Duncan Reservoir under operating regime Alt S73; and
- To collect additional data (factors that affect vegetation composition and cover) required for hypotheses testing and to address the management question.

The two hypotheses to be tested as part of this monitoring program in Year 4 (2018) are:

> "**H_{01}**: Alt S73 will not result in a decrease to the area and alterations in the species composition of both wetland and riparian vegetation communities; and
>
> "**H_{02}**: Reservoir elevations do not affect riparian distribution and abundance (cover) through the duration and frequency of root-zone flooding.

H_{02} is designed to investigate species-elevation-exposure time relationships, and results should facilitate predictions regarding plant community response to a given operating regime.

The key management question is:

- *Will the implementation of DDM WUP result in neutral, positive, or negative changes to riparian vegetation communities within the drawdown zone of the Duncan Reservoir?*

The DDM WUP CC identified two performance measures for testing the effects of Alt 73 on existing vegetation communities in the Duncan Reservoir (BC Hydro 2005). These are:

- **Riparian habitat productivity** – *long term median occurrence*: hectares of herbaceous riparian habitat in the reservoir drawdown zone to an elevation of approximately 8 m below full pool during the growing season (1 April to 30 September); and
- **Riparian vegetation** - *inundation tolerance*: hectares of *potential* herbaceous and shrub areas in the reservoir drawdown zone in the growing season (1 April to 30 September).

There was an expectation that Alt S73 would decrease the area of riparian vegetation around the reservoir drawdown zone compared to the prior operating regime (BC Hydro 2009) because the reservoir level would be held higher throughout late summer and early fall. However, the zone around the upper elevations may be exposed longer in the spring and early summer due to a slower fill rate, potentially providing a slightly longer pre-inundation growing season. Reduction of the wide variation experienced in the Pre-Alt S73 regime may also contribute to a more robust riparian plant community within the first metre drop in elevation from the full pool (576.7 m to 575.7 m).

The objectives for the Study Year 4 (this report), were to collect air photo data for mapping the vegetation distribution in the reservoir, field data collection of on-site habitats, and photo monitoring. Data collected in 2018 were added to the information gathered in past years and used for hypotheses testing and the final analyses for the full study field period for June vegetation in 2009, 2012, 2015, and 2018.

2.0 Methods

Sites were pre-selected by BC Hydro (2009) and the location of them is shown in Figure 2-1. The number of monitoring sites was determined by the budget available for field sampling and by the ease of access by BC Hydro, with a higher proportion of sites selected in areas with high enhancement potential (BC Hydro 2009). Site selection by BC Hydro was based on Moody (2002) with numbering changed to start from the south to the north along each side of the lake (BC Hydro 2009). The 12 sites monitored in 2009 had monitoring repeated in each of the subsequent years. Site 8 had to be dropped, as it was not captured during the flight because of incorrect UTM coordinates in the TOR (BC Hydro 2009). However, Site numbering remained the same as outlined in the TOR resulting in 12 sites monitored but numbered 1 to 13 with no Site 8. Site 14 was added to the aerial photography assessment in 2009 at the end of the reservoir and was not part of the field site monitoring component (Polzin et al. 2010).

2.1 Inter-annual Variation

2.1.1 Weather

Daily precipitation and temperature data were downloaded from Environment Canada's website for the Duncan Lake Dam Station at Meadow Creek, Climate ID: 1142574. The web site location is provided below[1]. Total monthly precipitation and mean temperatures for each study year are presented for 2009, 2012, 2015, and 2018. Additionally, total monthly precipitation and mean temperatures are shown from the start of Alt S73 (2008 to 2018).

Growing Degree Day (GDD)

Growing Degree Days (GDD) are used to estimate the influence on the growth and development of plants and insects during the growing season. GDD is based on the concept that development will only occur if the temperature exceeds some minimum development threshold, or base temperature (T_{base}). The base temperatures are determined experimentally and differ across plants that are adapted to warmer versus cooler climates. A regional review of the land, soil, and climate for crop potential in the West Kootenay, B.C. by Roussin (2014) used a base temperature of 5ºC for the GDD base calculations. A base of 5ºC was also applicable for regional cottonwoods (Kalischuk et al. 2001) and was applied for this analysis.

Growing degree days were calculated using the following formula:

$$GDD = [(T_{max} + T_{min}) / 2] - T_{base}$$

Where: GDD = Growing degree days,
T_{max} = maximum daily temperature,
T_{min} = minimum daily temperature; and
T_{base} = the base temperature, set to 5°C for all calculations.

[1] http://climate.weather.gc.ca/climate_data/daily_data_e.html?timeframe=2&hlyRange=%7C&dlyRange=1963-03-01%7C2016-07-20&mlyRange=1963-01-01%7C2007-02-01&StationID=1115&Prov=BC&urlExtension=_e.html&searchType=stnProv&optLimit=yearRange&StartYear=1840&EndYear=2016&selRowPerPage=25&Line=439&lstProvince=BC&Day=18&Year=2016&Month=8

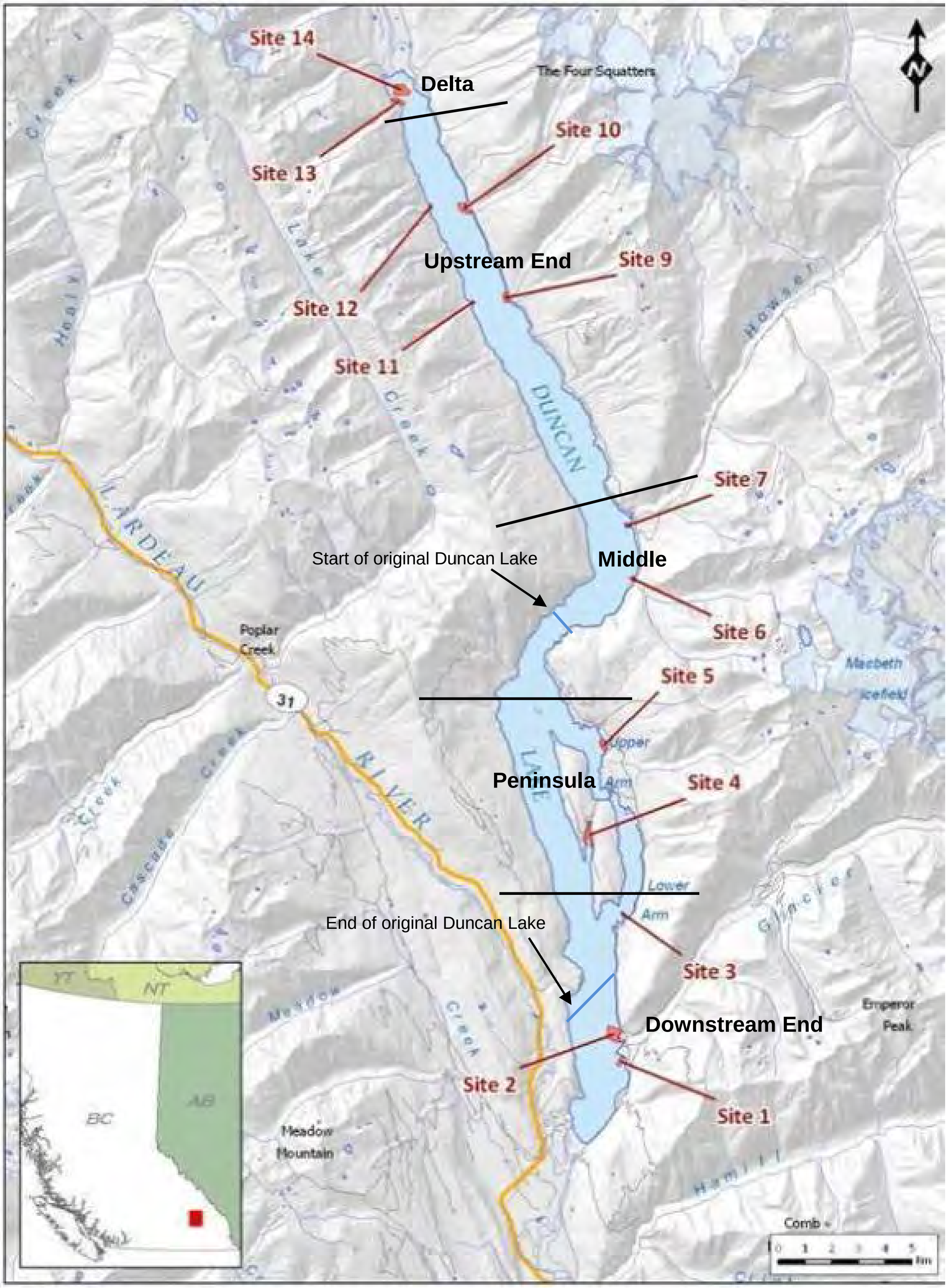


Figure 2-1: **The location of Duncan Reservoir and the 2018 sampling sites. Site 14 is used in air photo analysis exclusively.**

The GDD analysis was used for the early growing season (April through June) of the year in which field sampling occurred. All of the elevations and sites were above inundation at those sampling times. Subsequent days with less than a GDD of 1 were excluded and all days with GDD greater than 1 were counted to provide the spring GDD index for each year. The longer-term GDD results are provided, using the Hawkes and Gibeau (2015) method of presenting the results for the full growing seasons and for all years. This analysis revealed differences in the spring conditions and another analysis was undertaken to reveal the exposure versus inundation timing and durations through the growing season. The period in which the plants are exposed is important for colonization, growth and development and was assessed for many of the analyses in section 2.3.4 Environmental Factors.

2.1.2 Reservoir Regulation

The Duncan Reservoir level data were downloaded from Environment Canada's Water Survey website for Station 08NH127: located at Duncan Dam BC[2]. The previous year (2017) was used since it was the full growing season and fill regime cycle that would impact the vegetation of the following spring, which was monitored in June 2018. Data were summarized by day and by each week in the growing season (April to September), consistent with the method used for the previous years of monitoring.

The reservoir level data were used for the GIS analysis of the 85th percentile of exposed ground during the growing season, and to determine the per cent of the area exposed at each "high riparian potential sites" identified in the TOR (BC Hydro 2009). These included Sites 1 to 7, 10 and 13. The reservoir level data were also used for the calculation of exposure day's summations for all sites as assessed in section 2.3.4. Environmental Factors.

2.2 Mapping and Analyses of Vegetation Communities

2.2.1 Aerial Photography

Aerial photography was completed by Terrasaurus Aerial Photography Ltd., as subcontracted by VAST Resource Solutions Inc. (VAST). The work corresponded to the filling of the reservoir to reveal the sites above 566.7 m level, thus revealing the 10 m drawdown zones. As with prior years, thirteen selected sites were located around the reservoir (BC Hydro 2009). The June 6 2018 flight enabled 10 cm resolution (pixel size) aerial photo acquisition, and subsequent orthorectification, colour balancing, image sharpening and mosaic production. At that time, the reservoir level was 561.3 m, well below the maximum target level of 566.7 m.

The air photos were analysed using a Planar Stereo/3D Monitor for stereoscopic viewing on a computer monitor. Delineation of plant communities utilizing the orthorectified aerial photographs provided a measurement of the area colonized by different plant communities and the areas of bare ground. A comparison across years addressed the first null hypothesis (H_{01}) of whether changes in vegetation cover and plant community composition occurred within the drawdown zone after implementation of Alt S73. This study approach emphasized progressive changes with the new operating regime rather than a pre- versus post-regime comparison since there were limited analyses prior to the WUP.

[2] https://wateroffice.ec.gc.ca/report/real_time_e.html?stn=08NH127&prm1=46&prm2=-1

2.2.2 GIS Method

The use of GIS with the orthorectified aerial photographs allowed analyses of vegetation community types, vegetation community area calculations, and inundation times that occurred at the sampling sites. GIS analyses generated the data needed to address H_{01} and also contribute information for H_{02} analyses.

The contour, mass point, and break-line data for the study area were provided by BC Hydro in MicroStation V8 DGN format. All acquired elevation data were converted to an ArcGIS shape file format and imported into an ArcGIS geodatabase. Utilizing the 3D Analyst extension, elevation data were used to generate a Triangular Irregular Network (TIN) to represent surface morphology. The TIN was used to perform an analysis of the drawdown zone surface area, in which the surface areas above the weekly average reservoir elevations were calculated for each week during the growing season, for each of the 12 sites. Also calculated during this analysis were the surface areas of the drawdown zone exposed for 85 to 100 per cent of the growing season (April 1 - September 30) at each of the 12 sites. The TIN created for each site was used for 2017 elevation-based analyses because we sampled vegetation in the spring of 2018. GIS data submission is digital and was submitted separately from this document.

85th Percentile

There were nine “high riparian potential” sites identified by BC Hydro (2009). For these (Sites 1, 2, 3, 4, 5, 6, 7, 10, and 13), a weekly average reservoir elevation analysis was completed to determine the area of each site exposed during the growing season (April 1 to September 30) (as per the TOR 2009 requirement). Determination of the area of the drawdown zone that was exposed for 85 to 100 per cent of the growing season was also completed for each of the nine sites using the 2017 data (Appendix 2).

In addition to the 85th percentile, the per cent of the area exposed for each week during the growing season for each “high potential” sites in 2017 were calculated (Appendix 2). This was completed similarly to each of the previous study years. This information will contribute to the data used to assess the performance measure of “Riparian Productivity – *inundation tolerance*” and also the H_{01} (TOR BC Hydro 2009) in 2018.

2.2.3 Vegetation Mapping

Vegetation mapping utilized the baseline data parameters and the TIN created in 2009. Using the polygons delineated in 2009, changes in size, position, or composition of plant communities were updated to reflect the 2018 plant community mapping. The vegetation type (herbaceous, shrub, tree, bare) and community (community composition by dominant cover) codes established in 2009 were used in the 2018 analysis with secondary or tertiary cover revisions when required. The ‘dominant species’ (highest per cent cover of a vegetation community, bare ground, or wood, etc.) was used to distinguish between communities within a vegetation type. The original codes were utilized from 2009 and 2012 and two additional codes were added in 2015, to represent new communities. No additional codes were required for 2018.

Barren ground was assigned a vegetation type code ‘Bare’ and broken into two types. Bare 1 (B1) was bare ground with the dominant cover being physical, with bare ground, rock, wood, or a watercourse. Bare 2 (B2) was bare ground with trace amounts of vegetation with species listed in dominant 2nd and/or 3rd (Table 2-1). This was consistent with 2009, 2012, and 2015 methods. B2 vegetation was less than 15 percent cover for the delineated area, with ground truthing while in the field. The dominant species are listed using a seven-letter binomial code, with the first four letters of the genus and first three letters of the species name. A complete list of common and scientific names and codes is included in Appendix 1.

The vegetation type and community polygons from 2015 were layered over the 2018 orthophotos and coded utilizing an ArcGIS geodatabase. Polygons were revised to record new sizes and/or any changes in dominant species. The major attributes included: plant community (vegetation type); community dominant species one, two, and three; polygon area; site area; site aspect; transect line location (UTM coordinates); and transect line aspect (recorded as magnetic north bearings). The complete list of fields is located in the meta-data imbedded in the GIS files. This was consistent with the methods used in past reports (Polzin et al. 2010, Polzin and Rood 2013, and 2016).

Table 2-1: Vegetation type and community codes used for air photo mapping and the primary dominant species associated with the code.

Vegetation Type	Code	Community
Herbaceous (H)	H1	Common horsetail (Equi_arv.). (1)
	H2	Sedge (Care_spp). (2)
	H3	Smartweed (Poly_lap). (3)
	H4	Grass (any species without a code). (4)
	H5	Narrow-leaved collomia (Coll_lin). (5)
	H6	Small-flowered bulrush (Scir_mic). (6)
	H7	Lamb's quarters (Chen_alb). (7)
	H8	Spotted knapweed (Cent_mac). (8)
	H9	Yellow mountain avens (Drya_dru). (9)
	H10	Evening primrose (Oeno_vil). (10)
	H11	Yellow monkey-flower (Mimu_gut). (11)
	H12	Black cottonwood (Popu_tri) (<50cm tall). (12)
	H13	Nodding wood-reed (Cinn_lat). (13)
	H14	Wormseed mustard (Erys_che). (14)
	H15	Mouse-eared chickweed (Cera_vul). (15)
	H16	Silvery hair-grass (Aira_car). (16)
Shrubs (SH)	SH1	Black cottonwood (50 to 200 cm tall). (1)
	SH2	Willow – (50 cm to 200 cm tall). (2)
	SH3	All other dominant species (50 cm to 200 cm tall). (3)
Trees (TR)	TR1	Black cottonwood and shrubs (>200 cm). (1)
	TR2	All other dominant species (>200 cm). (2)
Bare (B)	B1	Bare ground – type listed under Dom1, 2, &/or 3 by the cover (wood – watercourse – bare ground). (1)
	B2	Bare ground with trace vegetation – dominant trace species listed 2nd and 3rd. (2)

Summaries of areas (ha) for each vegetation type (herb, shrub, tree, and bare) and each community from the mapping data were completed for all of the study sites, including Site 14 at the Duncan River delta, which was only analyzed through air photo interpretations. The analyses were organized by three factors (listed below), for the individual sites and for the total of the thirteen sites combined. Data summaries for the drawdown zones from vegetation mapping included:

1) Areas (ha) for each vegetation type and each community that occurred at each site;
2) Areas (ha) for each bare ground type that occurred for each site; and
3) Total area (ha) of all vegetation and bare ground at each site.

A summary of the Duncan Reservoir elevation analysis was completed to coordinate the 2017 reservoir levels with the 2018 vegetation cover. The 2017 reservoir levels were selected since this provided the inundation cycle that preceded the 2018 vegetation that was captured in the air photos in June, prior to the 2018 inundation and summer weather. The 2017 Alt S73 operating regime influenced the species and spatial distributions recorded in the spring of 2018 that represented the changes that occurred since the 2015 results. The 2009 data summaries reflect 2008 operating regime impacts and the first year of Alt S73 implementation. As a result, baseline data is not from Pre-Alt S73 rather it is after the first year of initiation of Alt S73.

2.2.4 Sampling Size Power Analysis

Determination of appropriate sample size is a trade-off between minimizing field expenses and still collecting sufficient samples to detect departures from the null hypothesis. The power of a statistical test is the probability that, when the null hypothesis is false, the statistical test(s) employed will find sufficient evidence against the null hypothesis (Schwartz 2009). This is also referred to as the likelihood of avoiding a Type II error (accepting a false null hypothesis). Sample size calculations are used to determine how many observations are required from a specific population, taking into account the sampling technique used, what data are collected, and the natural variation of the data.

Power analyses can be conducted *a priori*, to determine whether the sampling design of a project has a reasonable likelihood of rejecting a false null hypothesis. This is very useful in determining the appropriate sample size to avoid a Type II error. Power analyses can also be conducted retrospectively (or *a posteriori*). If a null hypothesis is *not* rejected, researchers may wish to determine if it was not rejected due to the small sample size. However, retrospective power analyses have been largely discredited in natural resource management and are strongly not recommended (Schwartz 2009; Steidl et al. 1997).

We performed an *a priori* power analysis to determine if our sampling design was sufficient to avoid Type II errors in the monitoring of vegetation per cent cover and species richness in the Duncan Reservoir area. Various formulae are available for power analysis, depending on sampling design. Generally, they use some estimate of the natural variation in the study population. This data may be obtained from pilot studies or prior knowledge from a similar population.

We used Equation 1 (Zuuring 1996):

Equation 1: $$\mathbf{n = (A^2 / \mathit{t}^2\, cv^2 + 1/N)^{-1}}$$

Where: n = sample size
t = critical value of $t_{(\alpha = 0.05)}$
cv = per cent of standard deviation/arithmetic mean
A = allowable Type II error percentage = 10 per cent
N = population size

When the population size is unknown, N is arbitrarily set at infinity, reducing the 1/N expression to effectively zero, thus:

$$\mathbf{n = \mathit{t}^2\, cv^2 / A^2}$$

The number of quadrates including quadrats with zero vegetation in 2009 was 536 for a power of 90 per cent with the number of quadrates in the field sampled was 2,685. Quadrats with zero vegetation were removed resulting in 509 quadrats required for a 90 per cent power level with 2,026 quadrats with vegetation.

The sampling design was modified in 2012 with transects: added, extended, reduced in length to end at 10 m drop in elevation, and sampling along transects at the start, middle, and end of a vegetation community band (2009 at every metre mark). This reduced the number of quadrats to 608 and changed the $\boldsymbol{t^2}$ $\mathbf{cv^2}$ values in the equation.

Schwartz 2009 and Steidl et al. 1997, do not recommend retrospective power analysis, however; one was performed for the reduced number of quadrats from the original design. This changed mainly the **cv** amount in the equation for determining the number of quadrats required to avoid Type II error. Table 2-2 shows the original power results and the 2012 results for the modified sampling design.

Table 2-2: Sample size (n) required to avoid Type II error for each quadrat size and the two types of data collected (vegetation per cent cover and species richness (# of species) at 90 and 95 per cent power for 2009. 2012 sample size power analysis for all vegetation.

Data collected (quad size)	2009 **n** 90 % power	2009 **n** 95 % power	# of quadrats 2009 with veg	2012 **n** 90 % power	2012 **n** 95 % power	# of quadrats 2012-2018 with veg
All cover (%)	509	1,488	2,026	125	500	608
All richness	13	52	2,026	11	45	608
Herb cover (%)	435	1740	1947	141	391	432
Herb richness	13	52	1947	11	42	432
Shrub cover (%)	14	55	69	3	12	36
Shrub richness	1	3	69	6	22	36
Tree cover (%)	2	4	10	6	26 (18 at 94%)	21
Tree richness	1	2	10	5	20	21

The large herbaceous population size resulted in no measurable difference between using our known population size (**N**) or by setting **N** to infinity. However, the shrub and tree known population (**N**) in 2009 was used for the power calculations for these two quadrat sizes therefor they were used for the 2012 calculations for comparison.

There are ample sampling quadrats to achieve 95 per cent power with the reduced number of quadrats from 2012 to 2018.

2.2.5 Data Analyses

Statistical analyses, including descriptive statistics, were conducted using SigmaPlot 12.5 (Systat Software Inc. San Jose California USA) and all tests were run at an alpha of 0.05. At the reservoir mapping level, all site data included the area in hectares per vegetation community and bare ground groups. At the field level, all site data was by transect line and/or by Site. Transect line data was quadrate measurements along each transect line.

The map area analysis used the Friedman Repeated Measures Analysis of Variance on Ranks for comparative testing of all communities for 2009, 2012, 2015, and 2018. One Sample *t* Test was used to compare and test the area covered by grass communities for 2009 to 2018. It was also used to test bare ground area and total vegetation communities for the four monitoring years.

At the field level analysis, the Kruskal-Wallis One Way Analysis of Variance on Ranks was used to compare and test for significant differences. This was done individually for total vegetation cover, total herbaceous cover, total shrub cover, and total tree cover.

Ordination analyses were completed using PC-ORD (McCune, B. and M.J. Mefford. 2011. PC-ORD. Multivariate Analysis of Ecological Data. Version 6.08 MjM Software, Gleneden Beach, Oregon, U.S.A.). We used ordination analysis which is a multivariate analysis for community analisys. Multivariate analysis is needed when the 'response' you wish to analyze is a composite of more than one individual response. It is simultaneously analyzing multiple responses for the relationships among the variables measured. A community of plants is characterized by a number of species whose local presence and abundance depends upon the interactions of those species as well as upon a myriad of environmental conditions (Peck 2010). We used non-metric multidimensional scaling for showing patterns, two-way cluster analysis for showing groups, and Mantel Test was used for testing among groups. We used Cover as a measure of abundance.

Non-metric multidimensional scaling (NMS, also abbreviated as NMDS) analysis for vegetation communities' area cover from air photo analysis was completed by sites for each of the four years with vegetation communities' areas as the response variable.

Some modifications were required which included:

- Bare ground data were removed;
- Grass communities combined by dominant grass species (H13, and H16) with the grouped grass (H4) community to be consistent with 2009;
- A new grouping of individual communities for weedy species was made and labeled HWeed. The communities grouped were: H7, lamb's quarters; H8, spotted knapweed; H14, wormseed mustard; and H15, mouse-eared chickweed;
- All identified outliers utilizing PC_ORD 6.08, Outlier Analysis, were removed; and
- Sites with large standard deviations were removed.

NMS was run four more times with a 3-dimentional solution result each time (250 runs per test). We compared all four graphs and found adequate consistency. We re-ran the NMS manually for a 3-D solution an additional 3 times resulting in consistent results (50 runs each test).

The final Monte-Carlo stress in the randomized data was:

- Axis 1 – P = 0.0392;
- Axis 2 – P = 0.0196; and
- Axis 3 – P = 0.0196.

The coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space were:

- Axis 1 – Cumulative R^2 = 0.297;
- Axis 2 – Cumulative R^2 = 0.456; and

- Axis 3 – Cumulative R^2 = 0.569.

Two second matrices were completed, one with bare ground and one with herbaceous, shrub, and tree responses by Site.

The main matrix with the Monte-Carlo stress in the randomized data was used in the Mantel test for testing H_{01} “Alt S73 will not result in a decrease to the area and alterations in the species composition of both wetland and riparian vegetation communities”. A small p-value indicates a significant association between the matrices, and a rejection of the null hypothesis of no relationship (Peck 2010). The Mantel Test was used for the testing of bare ground area and vegetation communities’ areas for the four monitoring years.

2.3 Field Sampling

2.3.1 Ground Level Photo-Monitoring Points

The photo-monitoring established in 2009 (Polzin et al. 2010) was repeated in 2018. The photo-monitoring points were set at specific distances along the transect lines that were established in 2009, and two additional transects with photo points were added in 2012. Photographs were taken at every two-metre change in elevation, with five pictures at each point, with the 4 directions: up the line, down the line, up the reservoir, down the reservoir, and downward over the herb plot. Photo documentation is provided in Appendix 5 and contact sheets of all photos taken in 2018 are in Appendix 6. One or two photos per transect line from 2018 were compared with the corresponding initial photographs from 2009 or 2012. Due to the dense canopy cover and shrub layers, comparative upland photos were taken where possible.

Site descriptions were provided in Polzin et al. (2010). Any changes to transect line lengths or the addition of transect lines are included in Polzin and Rood (2013). Appendix 1 shows site position relative to the reservoir, aspect, number of transect lines, slope, and length of the transect lines (Polzin and Rood 2013).

Previously, the drawdown zone had; three, referenced comparison photos for each transect line. For this final year of the report, 2018 photos were compared to the 2009 photos or 2012 if the transect line was established in 2012. Included are complete monitoring photographs (Appendix 6) and corresponding descriptions with descriptions located in Appendix 5. The summary table for each site includes 2018 results indicating differences or similarities between study years. The upland zone has a summary table included and photos are in Appendix 6.

The summary tables for each site list information for the Site as well as for the reservoir (total of all sites). For the individual Sites this included:

- Dominant species;
- Cumulative cover;
- Per cent of the site covered by the species;
- Per cent of the total reservoir cover represented by the amount at the site; and
- Site plant richness for 2009, 2012, 2015, and 2018.

For the Reservoir (all sites) tables included:

- Dominate plant species;
- Cumulative cover; and
- Reservoir plant species richness.

2.3.2 Sampling Design

The sampling design for site selection, size of sites, and four sampling periods were pre-set by BC Hydro (2009). Site locations are shown in Figure 2-1. The field sampling design from 2009 (Polzin et al. 2010) with the minor modifications in 2012 builds upon a literature-based hydrogeomorphic framework, in which riparian plants have particular water and substrate requirements for successful colonization (Auble et al. 1994, Mahoney and Rood 1998, and Polzin and Rood 2006). The Polzin and Rood (2013) report provided detailed information on some slight modifications that commenced during the 2012 field season.

Those modifications included additional transect lines added at three sites, and some transect lines were extended while others were shortened. The primary research question for this ten-year study related to prospective changes in vegetation cover or richness after the implementation of Alt S73 in 2008. This relates to the two specific hypotheses that were explored by the field surveys of vegetation in 2009, 2012, 2015 and 2018. In the first field study year, the 2009 vegetation inventory revealed extensive bands with similar vegetation types or barren zones. From this information, the sampling design was streamlined to only assess quadrats at the beginning, middle and ends of each cover type band. This substantially reduced the time required for the field inventory, with minimal sacrifice of information that was gathered.

Data Correction: From the change in methodology, vegetation sampling was not directly comparable between the 2009 inventory (Polzin et al., 2010) and the subsequent field surveys. We developed a 2009 data subset in 2012 that was intended to be comparable but there was an error which affects the comparisons of the 2009 survey with subsequent survey years of 2012 and 2015 (Polzin and Rood, 2013: Figures 9 and 18; Rood and Polzin, 2016: Figure 3-9). The prior reports do correctly present the results from each specific survey year, and it is only the interannual comparison between 2009 to 2012 that is affected. A corrected 2009 data subset was used for the analyzes in this final report.

The 12 sites monitored in 2009 had monitoring repeated in 2012, 2015 and 2018, with this forth inventory providing the final analyses for the project. Site 14 was added to the aerial photography assessment in 2009 but was not part of the field site monitoring component (Polzin et al. 2010).

Cross-sectional belt transects, stratified random sampling design, and sampling methods are described in detail in Polzin et al. (2010) and slight changes that occurred in 2012 are described in Polzin and Rood (2013). Transect lines had tag numbers attached to a tree or stamped into the flat top plate on a rebar post for the point-of-commencement (POC) and the bearing for the line was recorded. The established POCs and end-of-transect (EOTs) had their locations recorded utilizing a Trimble precision GPS. The 2018 sampling design and methods thus followed 2009, 2012, and 2015 protocols.

Analysis with belt transect lines

The analysis of vegetation along a river or reservoir should assess plant occurrences in four dimensions: the three spatial dimensions and the fourth dimension of time. Through this analysis, spatial and temporal patterns emerge, and the consideration of plant distributions relative to physical and biological factors can provide insight into the underlying processes. This understanding can contribute to management decisions, which may seek to encourage favoured vegetation and discourage unfavourable plants, such as noxious weeds.

Of the three spatial dimensions, the first or x-axis typically represents the longitudinal axis, the position along the upstream-to-downstream corridor of a river or river valley, or along the reservoir length (Figure 2-2). The transverse axis, or y-axis, is perpendicular to the longitudinal axis and represents the distance away from the reservoir shoreline. The banks rise up from the reservoir and this elevational rise provides the third spatial dimension, the z-axis.

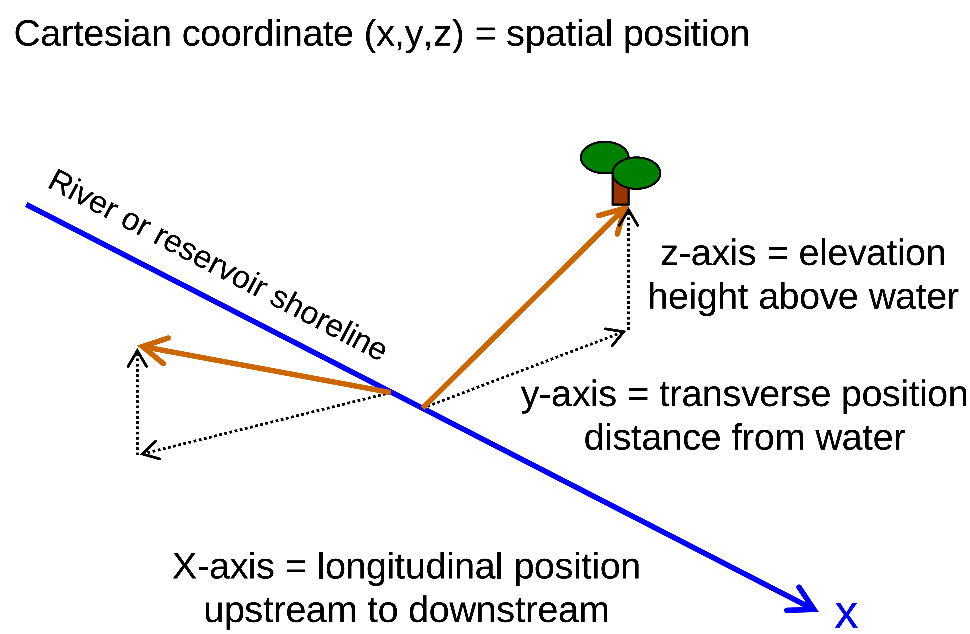


Figure 2-2: Riparian plant occurrence along three spatial dimensions.

Field sampling involves the assessment of a subset of individuals or groups, in an effort to understand the nature of the overall population. Relative to riparian vegetation, the task is to gather sufficient data to reveal the spatial occurrences of different plant species. Long-term monitoring to analyze responses to human alterations, such as through changes in reservoir regulation, requires a study system that facilitates repetitive observation, which in turn requires quick and accurate re-establishment of sampling quadrats relative to the three spatial dimensions.

As well, plant occurrences are not random within a drawdown zone, but instead there are typically bands of particular plant communities at particular elevations. These vegetation bands commonly follow the elevational contours of the reservoir banks. Different plant species and communities, or different age groups of particular plants, such as cottonwoods, occur at different elevations. These bands reflect the physical conditions imposed by the reservoir levels, with changes in reservoir stage or elevation that are responsible for plant removal by inundation scour, loss through mortality following inundation, or mortality due to drought-stress.

2.3.3 Vegetation Richness and Cover

The field monitoring of the reservoir drawdown zone and upland zone took place from June 6 to June 10, 2018. The 2018 monitoring crew members consisted of a senior riparian specialist, (same person since 2009) and two technicians working together for all sites. The sampling occurred between the elevations of 576.7 m (full pool) and 566.7 m for the reservoir drawdown zone and 576.7 m to 578.7 m for the upland zone. Established POCs were located and transect lines running down from full pool (drawdown zone) and running upland were setup using tape measures and bearings, repeating the same process used in Polzin et al. (2009) and Polzin and Rood (2013).

Tasks completed by the three-person field crew included:

- The sampling of vegetation species along the drawdown and upland sampling zone;
- Photographs were taken at the same photo monitoring points set up in 2009; and
- Surface substrate texture (class size) sampling along the complete length of the transect lines, with start and end points for each area where changes occurred, recorded as the corresponding metre mark.

The Daubenmire (1959) per cent cover sampling method was used for quadrat sampling (1 m^2, 8 m^2 and 50 m^2). Per cent cover of each plant species was estimated using per cent cover codes (Table 2-3) with an additional bracket added for trace cover (less than 1 per cent). Codes were recorded in the field and the mid-point was the data entry, with the mid-point for the new Code 1 determined as 0.1. This value was determined by averaging the actual estimated percentages for quadrats with less than 1 per cent, resulting in a 0.1 average in 2009. Additional details for the field procedures are reported in Polzin et al. (2010) and Polzin and Rood (2013).

Table 2-3: Per cent cover codes, with a description of the codes used for vegetation cover data collection.

Vegetation Per Cent Cover Codes		
	Per cent Coverage	
Code	*Range*	*Mid-point*
1	< 1	0.1
2	>1 - 5	2.5
3	>5 - 25	15
4	>25 - 50	37.5
5	>50 - 75	62.5
6	>75 - 95	85
7	>95 - 100	97.5

The three quadrat sampling sizes were referred to as:

- Herb quadrats (1 x 1 m = 1 m^2) sampled all herbaceous species (all heights) as well as any woody species ≤ 0.5 m in height. All shrub and tree species recorded in herb quadrats were marked;
- Shrub quadrats (2 x 4 m = 8 m^2) sampled all woody species between 0.5 m and 2.0 m in height. All tree species recorded within a shrub quadrat were marked for tracking purposes; and
- Tree quadrats (5 x 10 m = 50 m^2) sampled all shrub and tree species greater than 2 m in height and all shrub species that they occurred within a tree size quadrat were marked for tracking purposes.

Criteria for Dominant Species Selection

Upland Dominant Species were determined by selecting species with at least 18 per cent cumulative cover and greater than 18 per cent frequency for the upland reservoir transects, or at least 18 per cent frequency of occurrence for all reservoir sites combined. For this latter threshold, the species may have had less than 18 per cent cover. For selection, the observed plants were ranked in order of highest cover and frequency. Most species satisfied both criteria, but some occurred with frequencies greater than 18 per cent but less than 18 per cent cumulative cover.

Site dominant species selection was slightly different due to the limited number of quadrats for some individual sites. Site dominant species selection included species with at least 18 per cent cumulative cover from more than one quadrat and/or 60 per cent occurrence across the quadrats. Exceptions applied if the vegetation community only occurred in one quadrat for the site, the highest cumulative cover species was then selected (example Shrub cover for Site 3) or if all species recorded for the vegetation community only occurred along one transect line. Dominant species were ranked in order of combined highest per cent cover and highest frequency.

Reservoir Dominant Species were determined by selecting species with at least five per cent cumulative cover of the reservoir cover (total for all sites and all species) which was consistent with previous year’s selection criteria for the dominant species for the reservoir drawdown zone (transect data). Because of the increase in the number of quadrats per transect line in the drawdown zone (10 m change in elevation compared to the two-metre change in elevation for the upland), minimum frequency was not required as a selection parameter (required for upland dominant species because of the limited number of quadrats as measured over two metre change in elevation). The five per cent or greater cumulative cover criteria resulted in two dominant species in 2018. The past five or six dominant species (since 2009) were included in the 2018 list with a note that they were under the five per cent rule. Individual site dominant species were limited to the top five species with a maximum of six for some sites. The total cover for individual sites was used for the calculation of the per cent cover by species with the per cent rule applied. A maximum of six dominant species was selected if two species tied on the ranking or the sixth one was one of the five dominant species for the reservoir. Site 6 was an exception with six species recorded for the site. Site 6 was an exception as no species would qualify under the criteria. All species had frequencies of one, so frequency was ignored and percentage of cover for the site was used resulting in two dominant species.

Correspondences between Environmental Factors and Vegetation Characteristics

Physical factors were investigated in 2018, similar to the 2009 and subsequent analyses. The 2009 analyses revealed three primary factors, elevation, site, and substrate texture. The 2012 analysis (Polzin and Rood 2013) included inundation duration. Building on past analyses, all factors were analysed using the four years of data, along with the inhibitory inundation duration, with the inverse, exposure time.

2.3.4 Environmental Factors

There were seven independent, environmental factors identified in 2009 and two primary, dependent variables, vegetation cover and species richness. In 2012, the inundation duration was added to the environmental factor list with analysis completed for the 2013 summary report (Polzin and Rood 2013). In this final year of assessment and for hypotheses testing, inundation duration was inverted to produce the exposure duration, the number of days that position exposed during the growing season. Additionally, the per cent bare ground was added as an environmental measure for some correlation, although this is not independent from vegetation, since the two are opposing measures. Statistical testing, I assessed:

Site and Transect-based factors:

A. Site (including location);
B. Reservoir Side; and
C. Aspect.

Quadrat-based factors:

D. Distance;
E. Elevation;
F. Exposure;
G. Substrate;
H. Slope; and
I. Bare Ground.

<u>A. Site</u>

Site was the term for each of the 12 spatial locations along the reservoir that had been pre-assigned by BC Hydro. At each site two to four transects were implemented, reflecting site size. Site represented the first physical factor that was investigated, and all of the quadrats from the two or more transects were considered for each particular site.

Twelve sites were investigated, and we retained the previous numbering of 1 through 7, and 9 through 13, but the pre-assigned Site 8 had been excluded from our field sampling. For factor analysis, Site was treated as a nominal measure, since we anticipated that the site numbering would not reflect a systemic, incremental sequence relative to the physical conditions and influences on reservoir vegetation. Location provided another category with the numbers sequenced from 1 through 12, with increasing distance from the dam, regardless of the side of the reservoir.

Hypotheses:

- We anticipated that there would be a similarity with proximity and thus, closer sites would be more similar than distant sites.

- We anticipated that there could be a subtle upstream-to-downstream influence due to aspects such as climate, which would be influenced by distance from Kootenay Lake, versus the cooler, headwater valleys.
- We anticipated that sites along the different sides of the reservoir (east versus west) might differ due to influences such as climate differences associated with morning versus afternoon shading.

B. Reservoir Side

Reservoir side was the second physical variable, but this overlapped with Site. With the pre-determined site assignments that had been based on prior observations and access considerations (BC Hydro 2009), there were only three sites on the west side of the reservoir, limiting the variation of this prospective factor.

Hypothesis: Due to the influence of morning versus afternoon exposure, we anticipated that the west side would exceed the east side, relative to the vegetation cover and species richness of reservoir bank vegetation. However, due to the limited sampling along the west side (three sites), our expectations relative to a statistical effect were slight.

C. Aspect

For aspect, the down-slope direction of transects was considered relative to an eight-point scale representing the solar-drying index (Table 2-3). Thus, a south-facing aspect has a higher evaporative demand than a north-facing one, and with exposure to the afternoon sun, west-facing exceeds east-facing relative to site evaporation. The eight-point aspect score was treated as a nominal measure, since the sequence was not simply incremental.

Table 2-4: Aspect related solar-drying index used for aspect analysis.

Index number	Aspect	Bearing
1	N-NE, lowest drying	0 to 45^0
2	NW-N	315 to 360^0
3	NE-E	45-90^0
4	NW-W	270-315^0
5	E-SE	90-135^0
6	SW-W	225-270^0
7	SE-S	135-180^0
8	S-SW, highest drying	180-225^0

Because most quadrats at a site were aligned along relatively parallel transects, these shared the same aspect-index. Consequently, there was limited variation in the aspect of the quadrats. Also, since the aspect-index overlapped with Site, these two measures were not independent. We recognized that a transect-based study design limited the opportunity to investigate the possible influence of aspect, and we disfavoured models that included both site and aspect. We also explored cos (aspect) and sin (aspect) conversions to represent “northness” and “eastness”, respectively, as has been applied in some other vegetation ecology studies (Palmer 1993), but we favoured a single index for prospective site-drying.

Hypothesis: We anticipated that sites with aspects producing lower solar-drying index values would provide favoured zones relative to plant cover and species richness However, due to the limitation of the transect-based study design, our expectations for the detection of significant effects were limited.

D. Distance

Distance in metres represented the distance along a transect from the transect point of commencement (POC) at the approximate reservoir shoreline position associated with the full supply level (FSL). This positioning considered the digital elevation model or map, the triangular irregular network (TIN), and the observed dramatic transition from the upland forest to the reservoir zone. For factor analysis, Distance was treated as an ordinal measure, with variation in 1 m increments and divided into groupings. Since the bank profiles varied across the sites, the lengths of transects required to achieve the pre-planned 10 m drop in elevation varied considerably.

Hypothesis: We anticipated that perennials, including shrubs and trees, would be restricted to short distances from the reservoir FSL shoreline. We anticipated that annuals would occur more fully along transects, but that there would be progressive declines in covers, and possibly declining species richness with distance from the upland transition.

E. Elevation

We anticipated that quadrat elevations would reflect differences in slope and the associated transect profile, and would provide a stronger physical determinant than distance. We therefore developed two elevation measures. Elevation was estimated ($\pm$ 1 cm) for each quadrat based on linear interpolation between the survey points that were measured at periodic intervals along transects and any position of substantial profile change. The interpolated elevation was treated as a continuous, scalar measure, and for two- and three-way MANOVAs, it was treated as a covariate, or was grouped (binned). Data were collected for the full 10 m change in elevation below the full pool (altitude of 576.7 down to 566.7 m), as specified in the 2009 Terms of Reference) although vegetation was very sparse below the 8 m depth.

Hypothesis: While elevation would be correlated with distance, this is incomplete, since the slopes vary along and across transects. We anticipated generally similar patterns of vegetation versus elevation as versus distance, with declining cover and species richness with declining elevation. We predicted stronger patterns for elevation than for distance, since the elevation would better reflect the reservoir stage patterns and would provide greater consistency across transects, which vary relative to profile and slope.

We anticipated that perennials, including shrubs and trees, would be restricted to high elevations near the transition from the reservoir to the upland forest. We anticipated that annuals would occur more fully along transects, but that there would be progressive declines in vegetation cover, and possibly species richness with sampling that extended downward in the reservoir drawdown zone.

Since elevation and distance are strongly correlated, we further predicted limited improvement in statistical models with these two factors. We anticipated that elevation would provide a stronger correspondence than distance and could be a primary explanatory factor in the analytical models.

F. Exposure Time

In 2012 (Polzin and Rood 2013), an investigation into the inundation duration was initiated for the 2011 fill and drain from April 1 to December 9th (37 weeks). The results indicated that inundations times decreased vegetation cover as durations increased, with a strong correspondence (R^2 = 0.90). The methods were refined in 2018 to limit the analysis to the growing season (April to end of September (26 weeks). Inundation time was inverted to provide exposure time to represent a positive influence on the riparian vegetation.

For analyses, the exposure time provided an ordinal measure and for visualization and comparison across years we also considered groups, as undertaken by Hawkes and Gibeau (2015) and converted to the number of exposure days:

- 0-104 days = Red – strong to complete reduction of exposure time;
- 105 to 154 days = Yellow – strong to a moderate reduction from exposure time; and
- 155 to 183 days (183 days in the growing season) = Green – moderate to no reduction from exposure time.

Percentage of inundation time was completed for all months of the growing season for 2008 to 2017 (as per the TOR 2017 requirement). Sampling occurred in June of 2018 before the fill regime was above 566.7 m (-10 m bracket) so it was not included. This method follows what was presented by Hawkes and Gibeau (2015) as GDD but is actually Exposure/inundation duration. It is presented as per cent of inundation where the zero (0.00) represents complete inundation and 1.00 represents complete exposure using the structure from Hawkes and Gibeau (2015). The way Hawkes and Gibeau (2015) structured the data presented in the report removed actual temperature information and showed the inundation time since the number of days for GDD is reduced by inundation but not by temperature which is GDD. This had the same ranking as Exposure time presented above with percentage of inundation time as:

- 0.00-0.60 = Red – strong to complete reduction of exposure time;
- 0.61-0.84 = Yellow – strong to a moderate reduction from exposure time; and
- 0.85-1.00 = Green – moderate to no reduction from exposure time.

Hypothesis: We anticipated that exposure time would be correlated with elevation in a non-linear relationship. We anticipated similar patterns of vegetation versus exposure time, as with the general pattern with elevation, with declining cover and species richness with declining exposure. However, we predicted stronger patterns for exposure time than for elevation since the exposure time changes across the years. Exposure time would better reflect the reservoir stage patterns and would provide greater consistency across transects, which vary relative to slope and profile.

Since exposure time and elevation are strongly correlated, we expected limited improvement in statistical models with these two factors. Since we assumed that exposure time would provide a stronger correspondence, we anticipated that exposure time, rather than elevation, could be a primary explanatory factor in the analytical models.

However, previous reports compared different vegetation characteristics and substrate by elevation. Because of this, most graphs will continue to use elevation for comparison with the previous reports.

G. Substrate

For substrate, the Substrate Texture Index (STI) was calculated for each quadrat based on the field estimated per cent cover of silt (0.002-0.062 mm), sand (0.062-2.00 mm, gravel (2-64 mm), cobble (64-256 mm) and boulder (>256 mm) (Luttmerding et al. 1998). These sediments were assigned scores of 1 to 5, respectively, and the STI was calculated as the sum of the proportional cover (decimal value) x score, for the five sediment classes to provide a continuous value from 1 to 5. The STI value was rounded off to 0.1 and treated as a scalar measure, and groupings were established for analyses of variance.

Hypothesis: We anticipated that finer substrate texture would benefit plant establishment, growth and survival, because the finer substrate would better retain moisture and also increase capillarity, the moisture rise, above the water table.

H. Slope

The slope of each quadrat was estimated based on the calculated slope between each survey point (per cent, drop/run), with the intervening quadrats all receiving this average slope value. For factor analysis, the slope was rounded off to ±1 and treated as a scalar measure, and groupings were established for analyses of variance.

Hypothesis: We anticipated that shallow slopes would provide more favourable sites for seedling colonization and corresponding increased plant cover and richness. Following from studies along other reservoir shorelines (Rood et al. 2010), we also anticipated an interaction between slope and substrate, whereby fine substrates would be most favoured with shallow slopes, because finer substrates and associated vegetation are more vulnerable to erosion on steeper slopes.

I. Bare Ground

Bare ground was not one of the main factors since it was directly correlated with vegetation cover, as bare ground increases, vegetation cover decreases. However, woody debris, which occurred mainly along the first metre change in elevation down from full pool, was of interest and was part of the bare ground. Woody debris was first noted in the field as a possible factor impacting shrub and tree recruitment in 2012 and following the full pool overflow event in 2012 appeared to be a possible factor for reduced shrub and tree cover along the -1 m elevation change from full pool. Subsequently, Bare ground was assessed by Elevation and Site which included the types of bare ground such as woody debris, rock, water, and all other types of bare ground from sand/silt, pebble, cobble, etc. were labeled 'soil'. In 2015, the bare ground categories included: wood, soil, mud, rock, and water. The mud category was added to the soil category for comparison to the 2018 results. Some areas were sand while others were gravel. The finer scale differentiation was included in the 'Substrate Texture Index' analysis. Litter was not added to the bare ground means but was listed for comparison across sites. Woody debris as an important factor for reduced shrub and tree cover was also recognized by Hawkes and Miller (2016).

2.3.5 Vegetation Characteristics (quadrat based)

Vegetation characteristics provided the dependent variables in the study. As indicated in Section 2.3.3, in the field study, vegetation was assessed within each quadrat in each of the four study years, to provide two vegetation characteristics, cover and richness. Cover, provides an index of vegetation abundance while richness reflects vegetation diversity, and the Shannon-Weiner Diversity index incorporates both measures.

A. Vegetation Cover

Cover resulted from estimates of the proportional (per cent) extent of foliar cover over the quadrat. With multiple vegetation layers, cover occasionally exceeded 100 per cent, particularly for quadrats near the shoreline where shrubs occurred, and there could be tree canopy overhang. Cover was estimated and analyzed for the herbaceous (herb) layer and for the shrub layer. Tree cover was very sparse, limiting the analyses of this characteristic.

There were some barren quadrats and many sparsely covered quadrats and consequently the cover values were not normally distributed. A log (base 10) transformation somewhat normalized the distribution and consequently the log transformed herb cover or shrub cover was often analyzed.

B. Richness

Richness, or species richness, represents the number of different plant species within each quadrat, or along a full transect or for all quadrats at a site. There were some uncertainties about species assignments due to the lack of floral structures that are required for some identification, and there are also some unresolved issues related to the taxonomy for some plants such as sedges (*Carex* spp.) and horsetail (*Equisetum* spp.). Our assignments were consistent across years and changes over the decade of study should be less affected by the taxonomic uncertainties.

The richness distributions were skewed, and a square root transformation increased the spread for lower values, benefiting some analyses. For both cover and richness, the direct values and the transformed values were included for most of the statistical analyses, but we selected and often only present the metric that provided the best model fit.

C. Shannon-Weiner Diversity

Species richness is the number of different species recorded within a quadrat or along a transect line. Diversity takes into account species richness as well as abundance (cover). Computation of the Shannon-Wiener Diversity Index (H') or 'Shannon' indices for the sites was completed to provide an integrative measure of diversity. Midpoints of per cent cover classes were used as the measure of cover (abundance) and the Shannon Index (H') was calculated as follows:

$$H' = -\sum_{i=1}^{s} p_i \log_e p_i$$

where: p_i = proportion of the i^{th} species
s = the number of species in the community

This index increases with increasing species richness (number of species) and with increasing species evenness, the relative representation across the species.

The 2012 and 2015 'H' values had been reported (Polzin and Rood, 2013; and 2016) but these analyses were revised to adjust for the different transect lengths. The 2009 analysis was revised to include the quadrats as in the subsequent years, rather than for the continuous belt transects. The analyses are slightly different across the years since additional transects were added in 2012 and reassessed in 2015 and 2018. These provided slight differences and the results presented should be reasonably comparable between 2009 and 2012, and then directly comparable from 2012 through to 2018.

2.3.6 Analyses

A. Reservoir Sites

Our first analyses considered patterns of vegetation cover and species richness across the sites, and among the years. These analyses combined values from the two to four transects at each site, or for all quadrats for each site at each year.

These analyses considered sequencing by site number and also by location, with slight adjustments following the exclusion of the pre-determined Site 8, and sequencing of the west bank sites to provide a longitudinal pattern extending upstream from the Duncan Dam. Since there was substantial variation in vegetation cover that was apparently unrelated to the site or location we also rank-ordered the sites by 2009 cover to provide a third sequencing, as indicated in Table 2-4.

Table 2-5: Designations for vegetation study sites along the Duncan Reservoir, with the original, pre-assigned Site number (left column), the longitudinal Location, extending upstream from the dam (centre) and with Rank based on the average cover per quadrat in the 2009 sampling (1 = highest cover).

Site	Location	Rank 2009
1	1	5
2	2	6
3	3	4
4	4	2
5	5	3
6	6	12
7	7	11
9	8	7
11	9	9
10	10	8
12	11	10
13	12	1

B. Bivariate Correlations

To explore associations across the environmental factors and vegetation characteristics, we developed a composite Excel spreadsheet with each row representing a particular quadrat in a particular study year. For consistency, only the 2009 quadrats at positions measured in subsequent years were included. The quadrats from transects added in 2012 were included in the matrix but analyses were undertaken with or without these quadrats, since they were missing for 2009, which emerged as the most distinct year. For each row, all corresponding variables were included in sequential columns, first for the environmental factors and then for the vegetation characteristics. With about 600 quadrats x 4 years, this matrix included 2432 rows.

Since the same reservoir positions were assessed in the four study years, these were not independent. The reservoir inundation would have led to almost complete mortality at the lower elevations and thus, the vegetation status would be more independent across the years. There would be plant survival at the higher quadrats near the reservoir shoreline and for those zones the sampling could represent repeated measures rather than independent assessments. This study design was consequently somewhat confounded by pseudoreplication, but the large number of quadrats should provide confident outcomes. The complexity from repetitive assessments should be recognized and following from this we report the probabilities for associations and models, rather than relying on the standard $p<0.05$ criterion. Additionally, for the analytical and predictive modeling, we undertook analyses with only yearly data in addition to the composite four-year series. The yearly data include only single values for each quadrat, avoiding the complexity of repetitive sampling.

Relating to the study design, linear transects were selected in order to permit repositioning across the study years. Assessments of the same positions provided more direct outcomes relative to changes over time, strengthening the assessment of vegetation dynamics. Since the quadrats were substantially spaced along transects, no plants extended across quadrats, and these were thus treated as independent sampling units. However, quadrats along each transect are not fully independent, providing another complexity for some statistical analyses.

With the data matrix, analyses were undertaken with SPSS Statistics 19 (IBM Corp, NY, USA). Individual variables were plotted, and descriptive statistics were determined. The next focus was on paired considerations and all bivariate correlations were completed using traditional Pearson *r* calculations, which represent linear regressions, as well as two non-parametric rank-order tests, Kendall τ and Spearman rho, each with two-tailed tests of significance. The three correlations were highly consistent, and we generally present only the Pearson *r* values.

Due to an extensive number of bivariate combinations, which increases the likelihood of false positives, and the possible influences from aligned quadrats along transects, and from repetitive assessments of the same quadrats, we generally required $p<0.01$ for interpretation. Further, while statistical significance is often emphasized in scientific studies, the magnitude of association may be more important relative to the influence of different environmental factors. We thus required $r \geq 0.2$ as the association would be 4 per cent (per cent coefficient of determination, $R^2 = 0.04$).

Correlations were conducted with and without Site 13 which was situated near the Duncan River inflow delta at the upstream end of the reservoir and rather different in slope and condition from all of the other sites, but similar outcomes occurred. Key correlations are reported with exploration correlations presented in Appendix 4. The bivariate correlation analyses are best suited for continuous, quantitative variables, but were less appropriate for categorical variables and particularly site.

C. Factor Analyses – Multivariate Analyses of Variance

To investigate which environmental factors were most strongly associated with the vegetation characteristics that were observed during the field study, we conducted factor analyses or analyses of variance. This was suitable for categorical variables and also allowed for combinations of factors and the detection of interactions across factors. With SPSS, the General Linear Model (GLM) analysis was undertaken, first with Univariate analysis and site as a fixed factor. Next, GLM Multivariate Analyses of Variance (MANOVA) were undertaken with Cover or Log Cover and Richness or Square root (Sqrt) Richness as the dependent variables; the multivariate (bivariate) analysis sought the best models relative to the combination of the two primary vegetation characteristics. We commenced with analyses for individual environmental factors that displayed substantial bivariate correlations, and then advanced to two- and finally, three-factor MANOVAs.

The analysis revealed interactions, with combinations of two factors that would influence vegetation cover or richness.

D. Predictive Modeling – Multiple Linear Regression

The next statistical analyses sought to develop predictive models that could be useful to project possible outcomes from different environmental conditions, including different reservoir draw-down and refill regimes that would alter the exposure time. For these analyses, cover and richness were assessed separately since there might be different objectives with adaptive management.

This SPSS analysis applied the 'Regression, Automatic Linear Modeling' (ALM) module but this was chosen to speed up the different applications and we did not rely on the default Build or Model Options but instead used 'custom field assignments', and other combinations. We generally applied a Forward stepwise model, and the various options are reported for the different analyses in the 3.0 Results section.

E. Ordination

To explore patterns of plant species distribution, we conducted two types of ordination analyses. Free Ordination utilizing NMS, used for looking for a pattern and Classification using two-way cluster analysis to look for groups within the data set. Ordination analyses were completed using PC-ORD (McCune, B. and M.J. Mefford. 2011. PC-ORD. Multivariate Analysis of Ecological Data. Version 6.08 MjM Software, Gleneden Beach, Oregon, U.S.A.).

For the Free Ordination of plant communities by Cover, we selected eighteen most abundant and highest occurring species for the four study years. Some species that were abundant in one year may not have been a dominant species in subsequent years but the most representative for the four years were selected. Nonmetric multidimensional scaling (NMS) was selected for the analysis. NMS analysis avoids assumptions that are rarely met with community data required for PCA (Free Ordination for linear model form) (Peck 2010).

NMS analysis for ground level vegetation cover (18 dominant species) was completed for Sites for each of the four years and by Transects for each of the four years.

Analysis by Site for each of the four years used 18 dominant species. The result of the manual run NMS Monte Carlo test (250 runs) was Axes 1 and 2 with a P = 0.004 for a two-dimensional analysis. This was rerun three times with different seed numbers with very similar results. The coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space were:

- Axis 1 – R^2 cumulative = 0.523; and
- Axis 2 – R^2 cumulative = 0.694.

An explanatory matrix was overlaid with responses Site, Slope, Substrate, Woody debris cover, and Vegetation grouped by types – Grass, Wetland, Riparian, and Weedy classes.

3.0 RESULTS

3.1 Inter-annual Variation

3.1.1 Weather

Weather data is presented by total monthly precipitation and mean monthly temperatures. Spring weather is important to resume plant growth prior to the reservoir re-filling. The weather comparison for the four study years (2009, 2012, 2015 and 2018) revealed that 2015 had the warmest June while 2018 was warmest in May (Figure 3-1). Otherwise, temperatures were quite similar during the growth season across the study years.

The precipitation for the study years (Figure 3-1) shows a great deal of variation for April through June across sampling years. The amount of precipitation that varies between years can have more of an impact on the vegetation growth in the spring before inundation for the sampling year. Dry hot weather resulted in shorter plants and changes in some of the dominant species communities. The 2009 weather data was missing data for March, May, and December so data from the nearest station with very similar weather patterns, Kaslo (Climate ID: 1143900), was used for those months. The total precipitation in May 2009 was the highest (83.4 mm) for all sampling years (Figure 3-1). The May total precipitation for 2012 was 31.4 mm lower than in 2009 and the lowest for the monitoring years. Total precipitation for the monitoring years 2012 to 2018 were similar. June total precipitation in 2012 was extremely but the majority of the precipitation occurred after sampling and would not have influenced the vegetation analysis for that year.

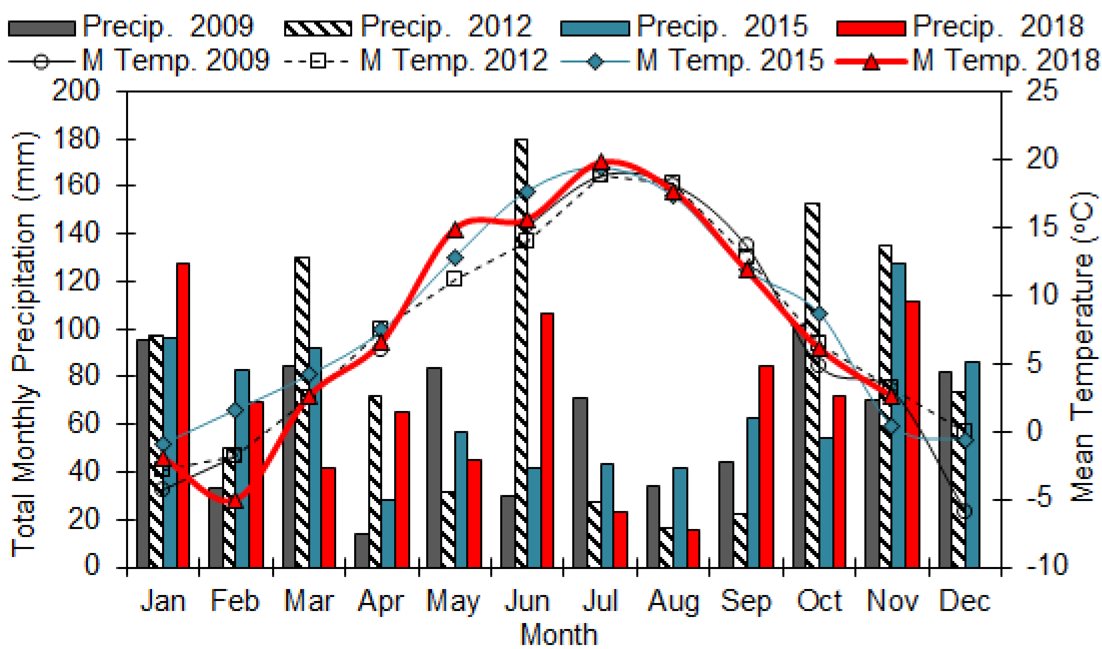


Figure 3-1: Monthly mean temperatures and the monthly total precipitation (Precip.) for the field study years of 2009, 2012, 2015, and 2018. The regional growing season is primarily from April to September.

Figure 3-2 contains all years since the start of the new flow regime, Alt S73, providing the 11 years of the implementation. Extreme precipitation (>160 mm of precipitation in one month) events occurred, January 2011, June 2012, and October 2016.

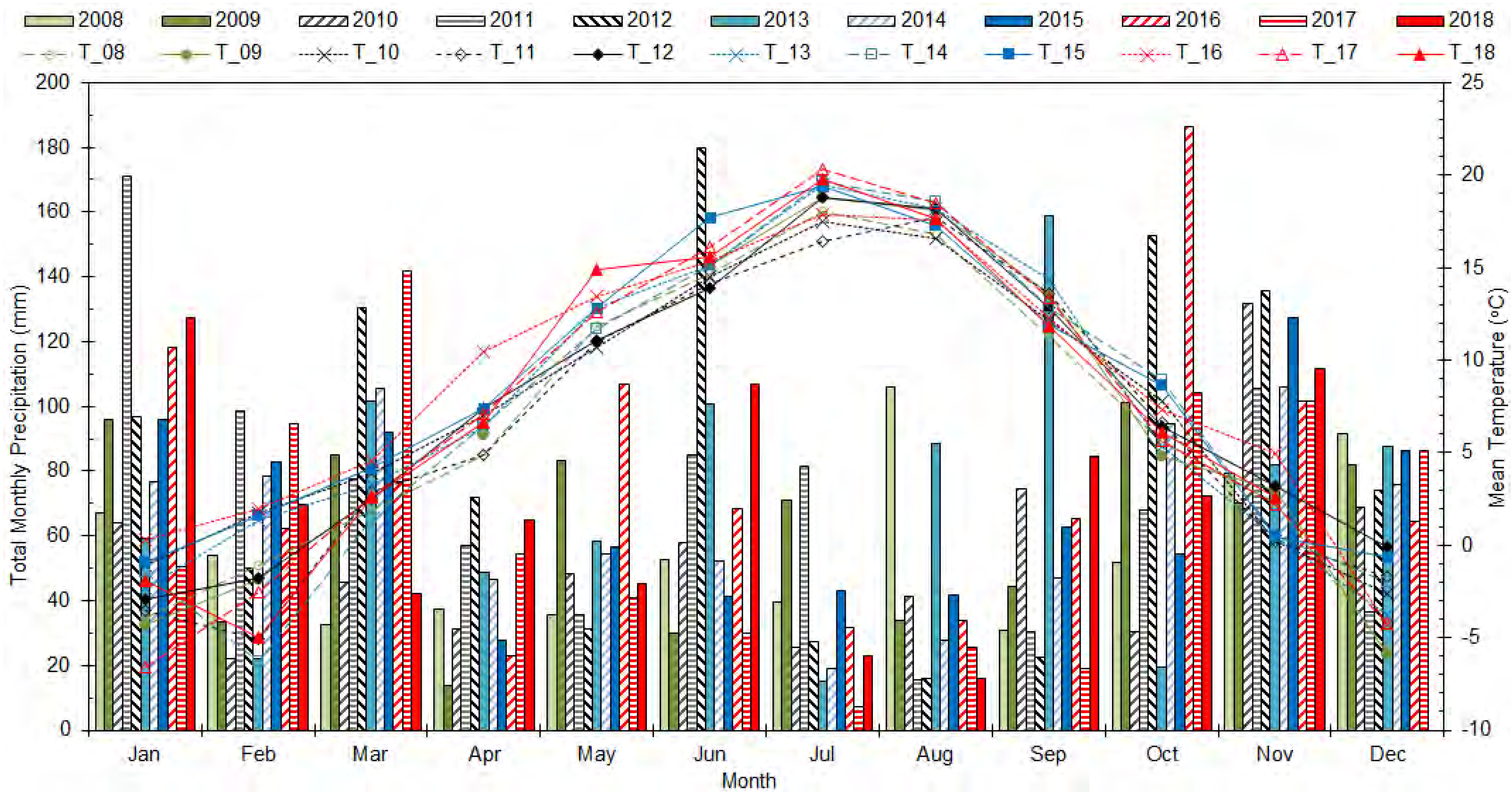


Figure 3-2: **Monthly mean temperatures (T) and the monthly total precipitation (Year.) for the Alt S73 project years of 2008 to 2018.**

Growing Degree Days

The spring season numbers of Growing Degree Days (GDD; days with GDD of 1 or greater were counted as one day) have direct effects on the vegetation for the spring months up to the end of the sampling year, with field sampling occurring in June. The full elevation sampling range from 0 to 10 m below full pool was exposed during this time. Some variation in the number of GDD occurred during April, leading to later starts to the growing season in 2009, and to a lesser extent in 2018 (Figure 3-3). The reduced days in June (2015 and 2018) occurred at the 566.7 m elevation bracket (-10 m) from inundation after field sampling was complete for those years. This reduction in Exposure time is presented in Section 3.3.7 Exposure for the elevation band from full pool (576.7 m) to 566.7 m in the drawdown zone.

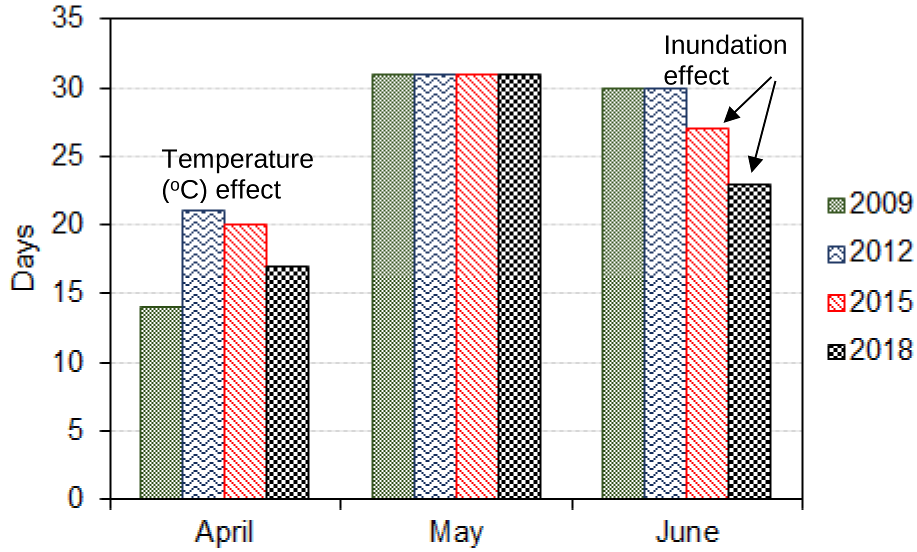


Figure 3-3: **The number of days with at least 1 growing degree day for the months of the spring growing season across sampling years. June's reduced days are inundation which received a 0 for the growing day, not growing degree day reduction.**

3.1.2 Reservoir Level

The Dam operation and reservoir levels with Alt S73 differed from the 1968-2007 operating regime in the following ways:

Pre-2008: The average reservoir level from 1967 to 2007 (Mean 67-07 black line on Figure 3-4) reached a fill level of 575.7 m by July 29 and stayed at this level to August 30 (full pool is 576.7 m). During this time the average variation (maximum stage – minimum stage) for the average reservoir fill level of 575.7 m was 15.1 m using all years. Removal of the three very low stage years (1973, 1992, and 2001) resulted in an average variation of 3.0 m. From September 1 to early December, there was a gradual draining to 569.8 m. The levels then dropped rapidly from December through March 20 to 550.5 m. Levels were stable around 550 m for the remaining time in March until April 30, when levels rose quickly to 575.7 m (one metre below full pool). The average variation for the lowest levels (March 21 to April 30) was 10.8 m. Figure 3-4 shows the substantial annual variation during the Pre-Alt S73 years.

Alt S73: The Duncan Dam WUP project Alt S73 regime involved the reservoir:

- Reaching full pool between August 1 and August 10;
- After which the reservoir elevation would decrease to 575.5 m; and

- Be maintained within 0.3 m of this level until September 5 (BC Hydro 2009).

Following the implementation of Alt S73, the actual regime from 2008 to 2018 had the reservoir reaching full pool or near full pool from July 21 to August 24 with an average variation of 3.4 m (the difference between the maximum and minimum daily level) during this time. The average level was maintained within 1.6 m of full pool (July 21 to August 24). From August 24 to September 5, the level decreased to 575.3 m and maintained within 0.5 m.

The annual variation for peak fill levels has substantially lower compared to Pre-Alt S73 of 15.1 m for all years. However, it was slightly higher compared to the Pre-Alt S73 when the three extremely low-level years were excluded. Drawdown reached the lowest level of approximately 547 m in April to the first week in May with reduced variation compared to Pre-Alt S73 regime (average Pre-Alt S73 = 10.9 m, average Alt S73 = 0.9 m) (Figure 3-4).

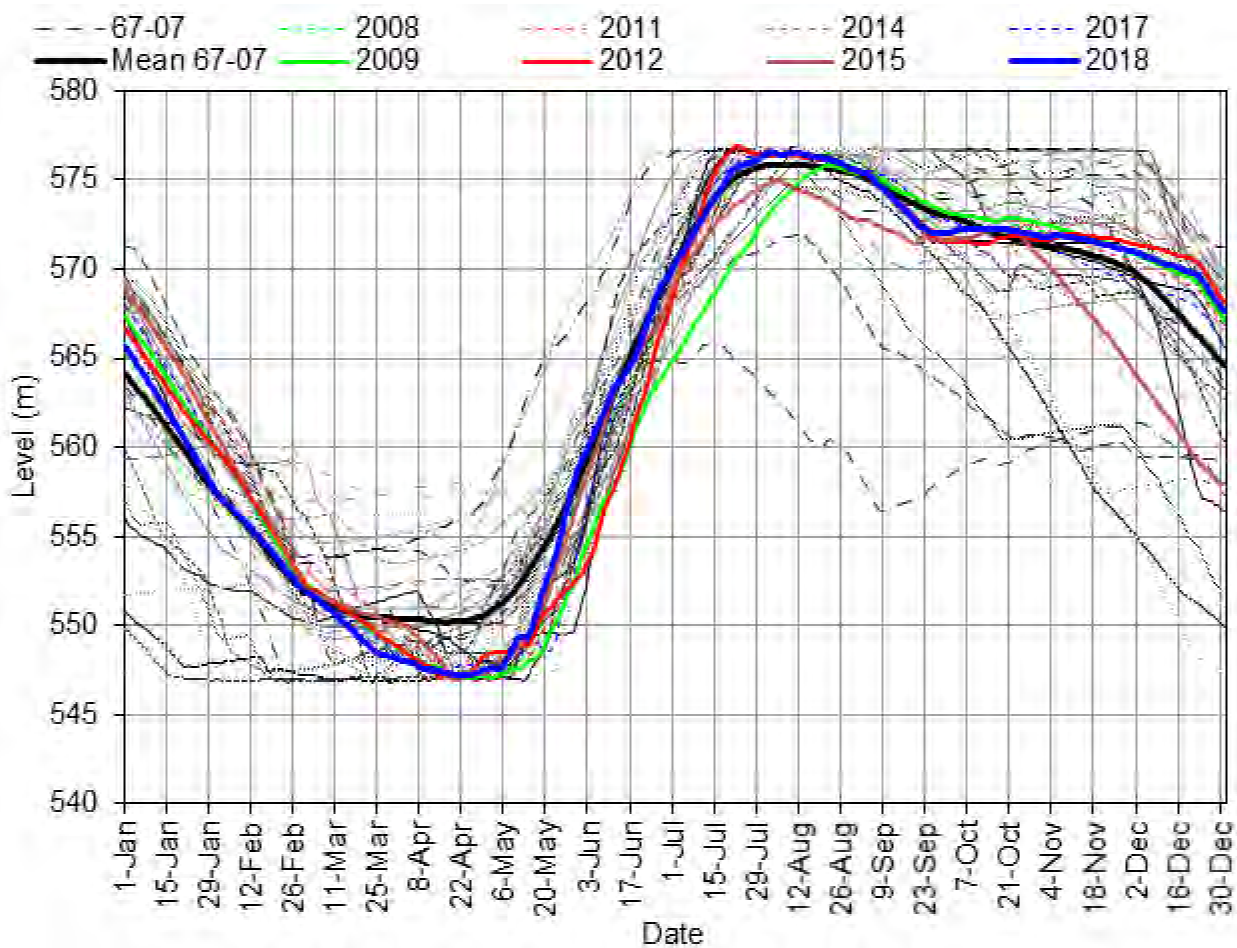


Figure 3-4: Mean Daily Water Levels (m) for Duncan Reservoir at Duncan Dam (WSC Station 08NH127) 1967 – 2018. Bold lines indicate years of vegetative analyses.

Figure 3-5 shows the 2017 and 2018 levels with the yearly variations from 1967 to 2007 removed to increase visualization. The 2017 fill regime displayed a similar pattern to 2014, 2011, and 2008 the years that proceeded the vegetation sampled in June, prior to reservoir filling.

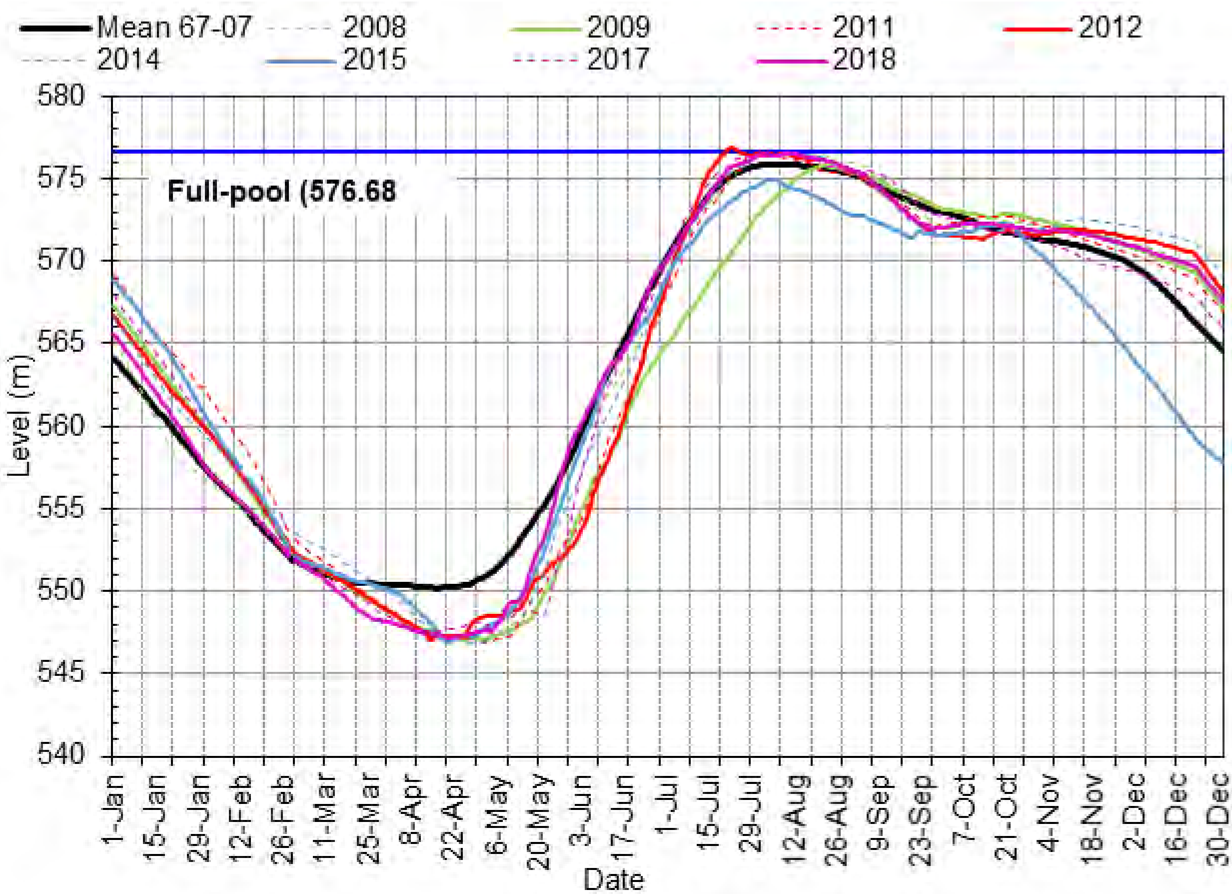


Figure 3-5: Mean Daily Water Levels (m) for Duncan Reservoir at Duncan Dam (WSC Station 08NH127) 1967 – 2018. Bold lines are field years; dashed lines are years influencing the June field days the following year.

In contrast, the sampling year fill regimes varied across years, with incomplete reservoir refilling in 2009 and especially in 2015. Figure 3-6 has the Y axis scaled expanded from 572.0 m to 578.0 m to dephasing the variation that occurred between the sampling years and the previous year fill regimes. This reveals the over-filling of the reservoir in the river flood year of 2012, although as previously indicated, this occurred after the 2012 vegetation sampling in June (Figure 3-7).

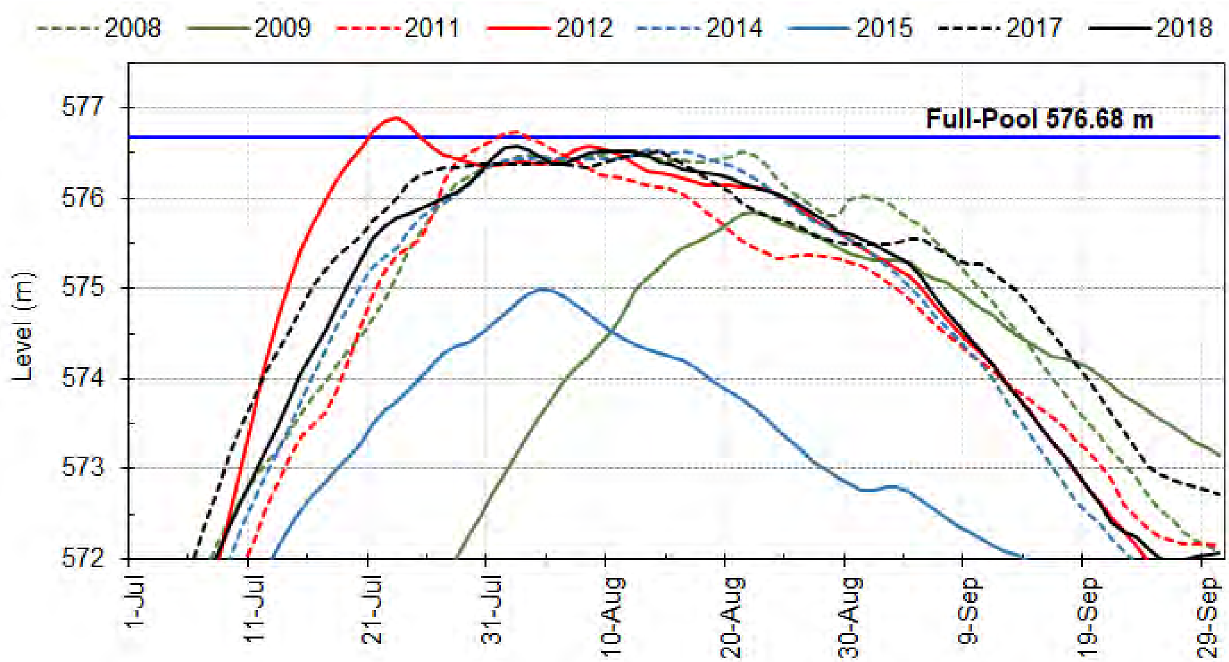


Figure 3-6: Mean Daily Water Levels (m) for Duncan Reservoir at Duncan Dam (WSC Station 08NH127) for July 1 to September 30 with the top 4 m change in elevation from full pool shown.

The scheduling of the vegetation surveys and air photos resulted in the transect lines being fully exposed, with no inundation during the week of field work. In 2018, field work started on June 6, 2018, and air photo acquisition occurred on the same day. Field work was completed before reservoir levels were above 566.7 m (the end of transect lines) (Figure 3-7). Figure 3-7 illustrates the fill regime for 2017 and 2018 with reservoir levels marked for each week. The 85th percentile of exposed ground and full pool are shown for reference with results that follow.

After field sampling during the end of June and the remaining growing season, it is the exposure time that impacts vegetation growth, survival, and species that occur along the reservoir drawdown gradient for the remainder of that growing season. Additionally, precipitation is a factor for the exposed elevations (within the 85-percentile exposed drawdown zone) during the summer months of the growing season. Growing degree days is not a direct factor as the temperature (degrees) during the summer months is not the limiting factor, the limiting factor is days the elevation is exposed for growth to continue. GDD does not give information about precipitation during the days exposed. Therefore, GDD is not used in the analysis, Exposure time is used which is the reverse of inundation duration.

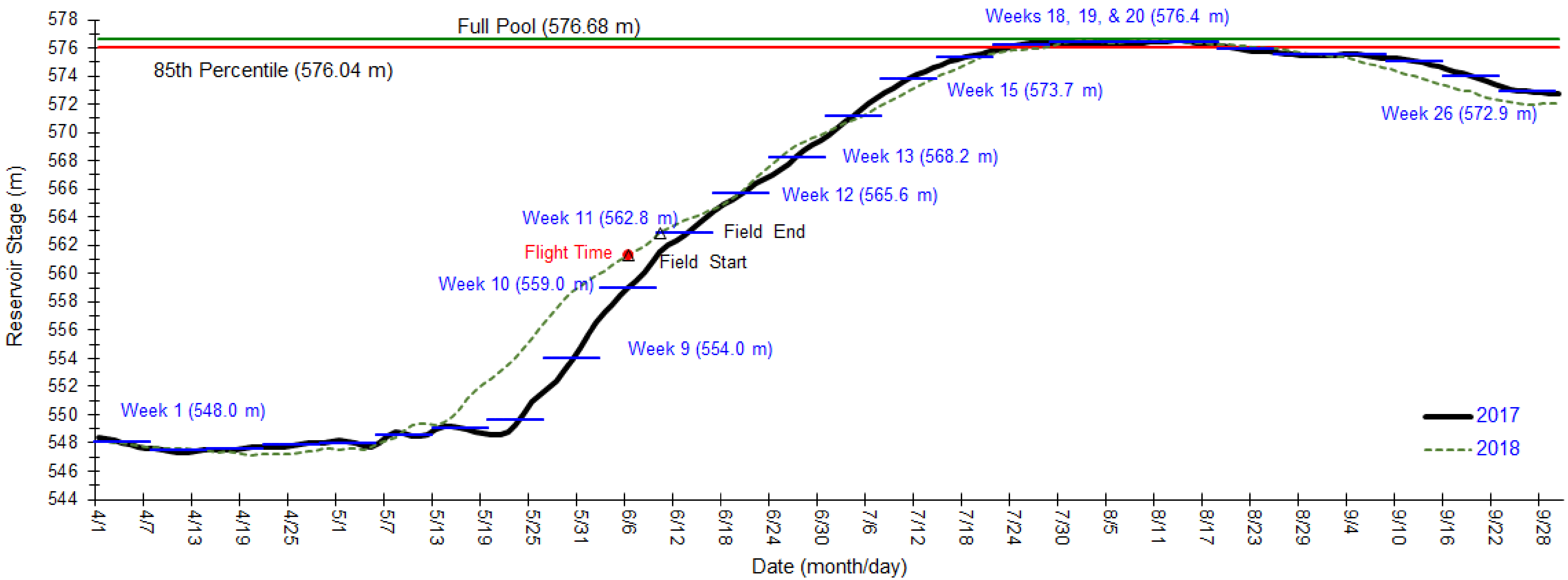


Figure 3-7: **The 2017 reservoir stage during the growing season (April to September 29) (solid black line) with the average weekly stage (26 weeks; short blue lines) and the 85th percentile level (red line). Flight time and field data collection times are indicated as a red dot and black triangles, respectively and correspond to the 2018 reservoir stage. Full pool, which is the upper limit of the reservoir water level and the start of the drawdown zone, is shown as a green line.**

3.1.3 The 85th percentile

The 2018 assessment used the 2017 reservoir levels as these represented the prior inundation cycle, which influenced the 2018 vegetation. The 2018 fill regime has not occurred yet, therefore, the previous fill and drain regime is the most current influence on the vegetation occurring in the following spring. Reservoir fill levels were analysed for the growing season, starting April 1, 2017, and extending to the end of September 2017. The previous years of study used the same analyses utilizing the previous year reservoir levels for the subsequent study year when sampling occurred.

The water levels at the 85th percentile for the reservoir were:

- 576.14 m for 2008;
- 575.50 m for 2011;
- 576.00 m for 2014; and
- 576.04 m for 2017.

The areas for each site exposed for 85 to 100 per cent of the growing season for the "high riparian potential for enhancement sites" (Sites selected by BC Hydro (2009) for the 85th percentile analysis) were compared across years and revealed that the area exposed at the 85th percentile was lower in 2011 (i.e. larger areas were exposed in 2011) while 2008, 2014, and 2017 were similar across sites (Figure 3-8). Site 6 displayed the smallest decrease compared to 2011, but has had almost no vegetation cover since 2008. Site 7 also had minimal vegetation cover since 2008 and consequently, neither Site 6 nor 7 would be assessed as "high riparian potential for enhancement sites", differing from the initial recommendation (BC Hydro 2009). The 2017 data for each week and site is located in Appendix 2.

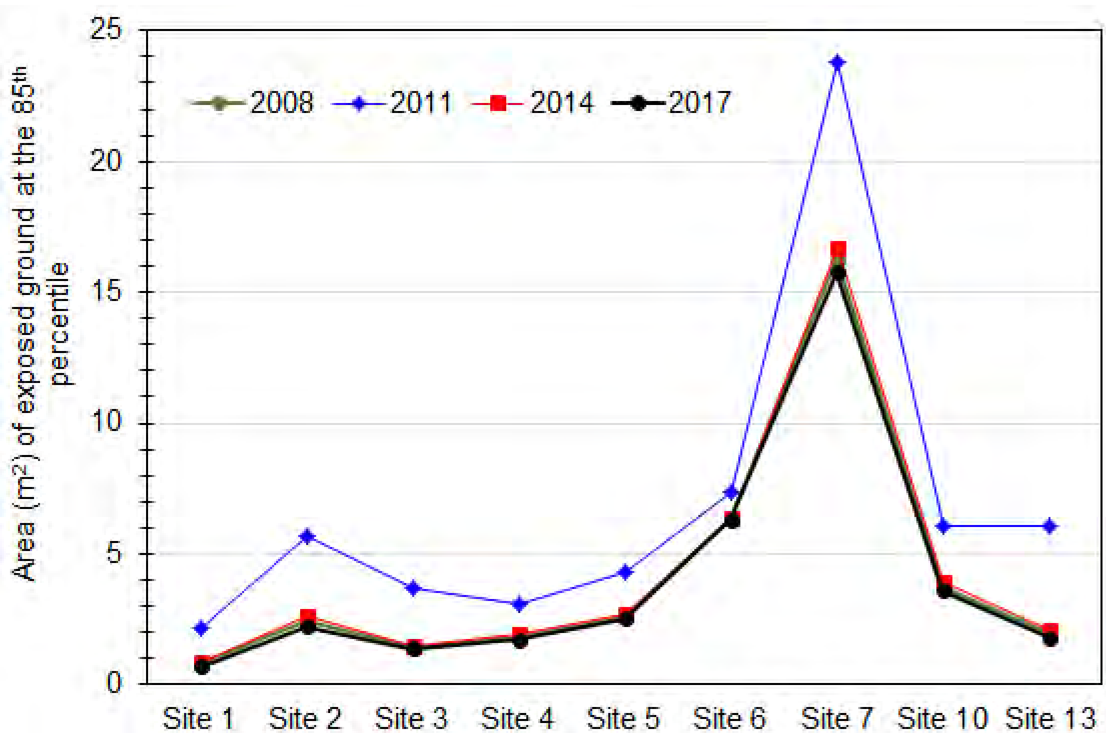


Figure 3-8: The per cent of the site within the drawdown zone that was exposed for 85 to 100 per cent (85th percentile) of the growing season for 2008, 2011, 2014, and 2017

In 2017, Site 1, the site closest to the dam, had zero per cent of the drawdown zone exposed for weeks 17 to 20, and week 21 had one per cent exposed (Appendix 2). No other sites had zero per cent exposed during the same time frame. Sites 2, 3, 4, and 13 had one per cent exposed during the same time frame (Site 2 had two per cent exposed for week 17 and then one per cent for the remaining time frame). This was similar to Study Year 3 (2014 reservoir levels) with zero per cent exposure for Site 1 starting one week later (weeks 18 to 21). Sites 2, 3, 4 and 13 all had one per cent exposed during the same time frame in 2014. Note that Site 13 had three to four metre change in elevation across the site and all of the other sites have a 10 m change in elevation.

Site 13, the site furthest from the dam, is located on the edge of the delta. Elevation profile was limited to the first three to four metre change in elevation. This resulted in a greater area exposed as the reservoir drained compared to the other sites that were similar during weeks 17 to 20. The areas exposed by week 26 were:

- Site 1 – 12 per cent;
- Site 2 – 25 per cent;
- Site 3 – 20 per cent;
- Site 4 – 14 per cent; and
- Site 13 – 69 per cent.

Only minor areas of the draw-down zone are exposed for most of the growing season for Sites 1 to 12.

3.2 Mapping and Analyses of Vegetation Communities

The aerial photograph delineation of the vegetation type Bare (including B1 and B2) showed increases across years for total area of Bare ground (rock, wood, bare ground, water etc.) for some Sites, (Appendix 2, Figure 3-9, and Figure 3-10). Conversely, the vegetation type Herbaceous (Herb) displayed decreases in areas for most Sites compared to previous years. There was one exception, the delta zone Site 13 had an increase in Herb cover in 2018, with 4.7 ha compared to 3.9 ha in 2015. The largest decreases in herbaceous types occurred at the same Sites that experienced the largest increases in Bare ground area indicating transitions between these two cover types.

The Shrub vegetation type (height <2 m) had a small total area of cover when it occurred on a particular Site from the beginning of the study. Similar to previous years, there was a decrease in overall Shrub cover at the sites. Some of the decreases was the transitioning from Shrub type to Tree type. The large decrease in Shrub type in 2015 was mainly due to the increase in woody debris near full pool resulting from 2012 above full pool levels in August.

The ‘Tree’ vegetation type (height >2.0 m) occurred at six sites in 2018 and had 0.86 ha for the reservoir study sites. Tree vegetation type represented a very small area in 2009 (0.0034 ha) for one site, which increased to 0.16 ha in 2012 (the same one Site) and decreased slightly in 2015 (0.12 ha) (with two Sites) and increased in 2018 (0.86 ha).

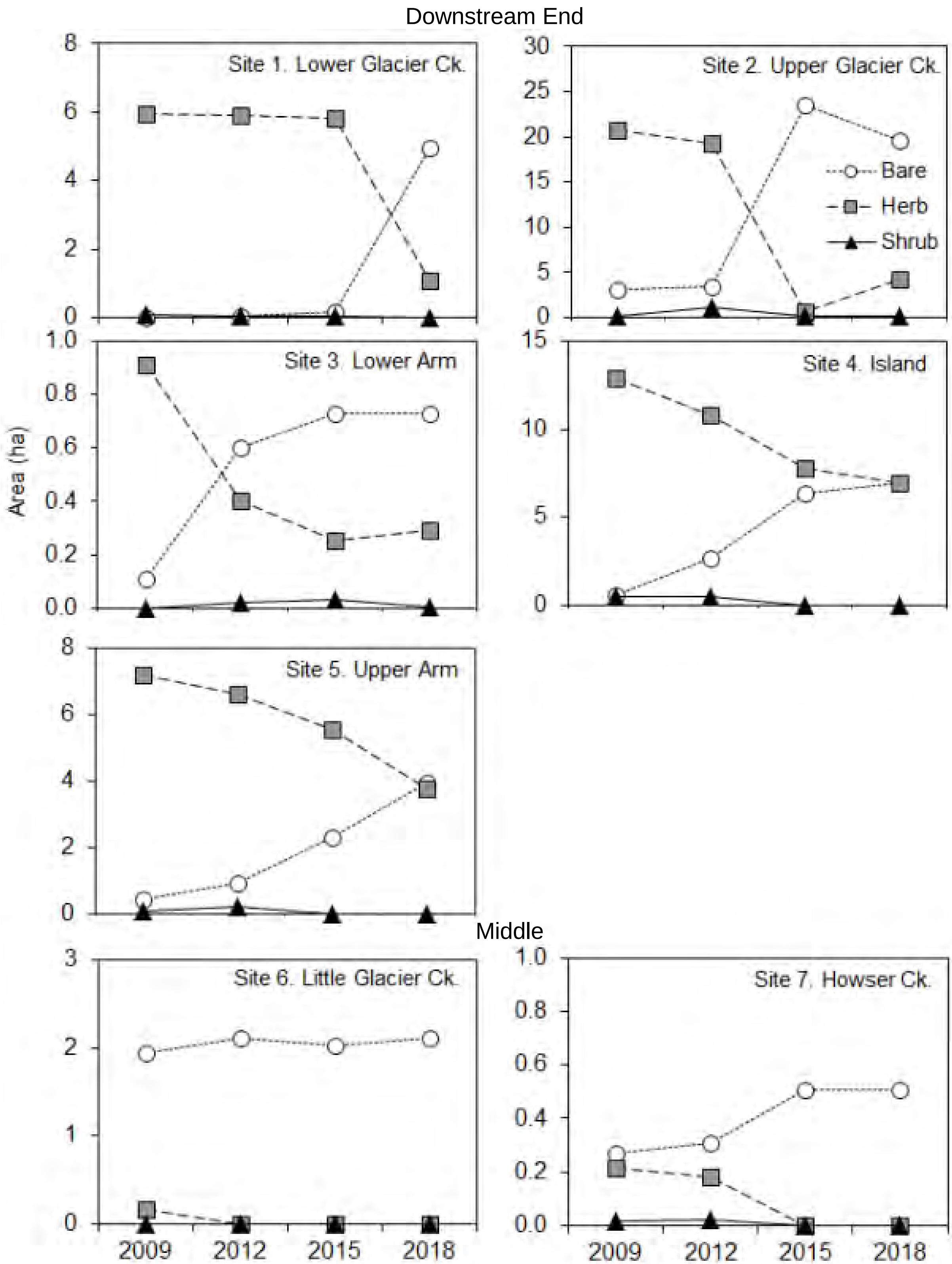


Figure 3-9: **Total area (ha) for Sites 1 to 7 for Bare ground, Herbaceous, and Shrub cover for 2009, 2012, 2015, and 2018.**

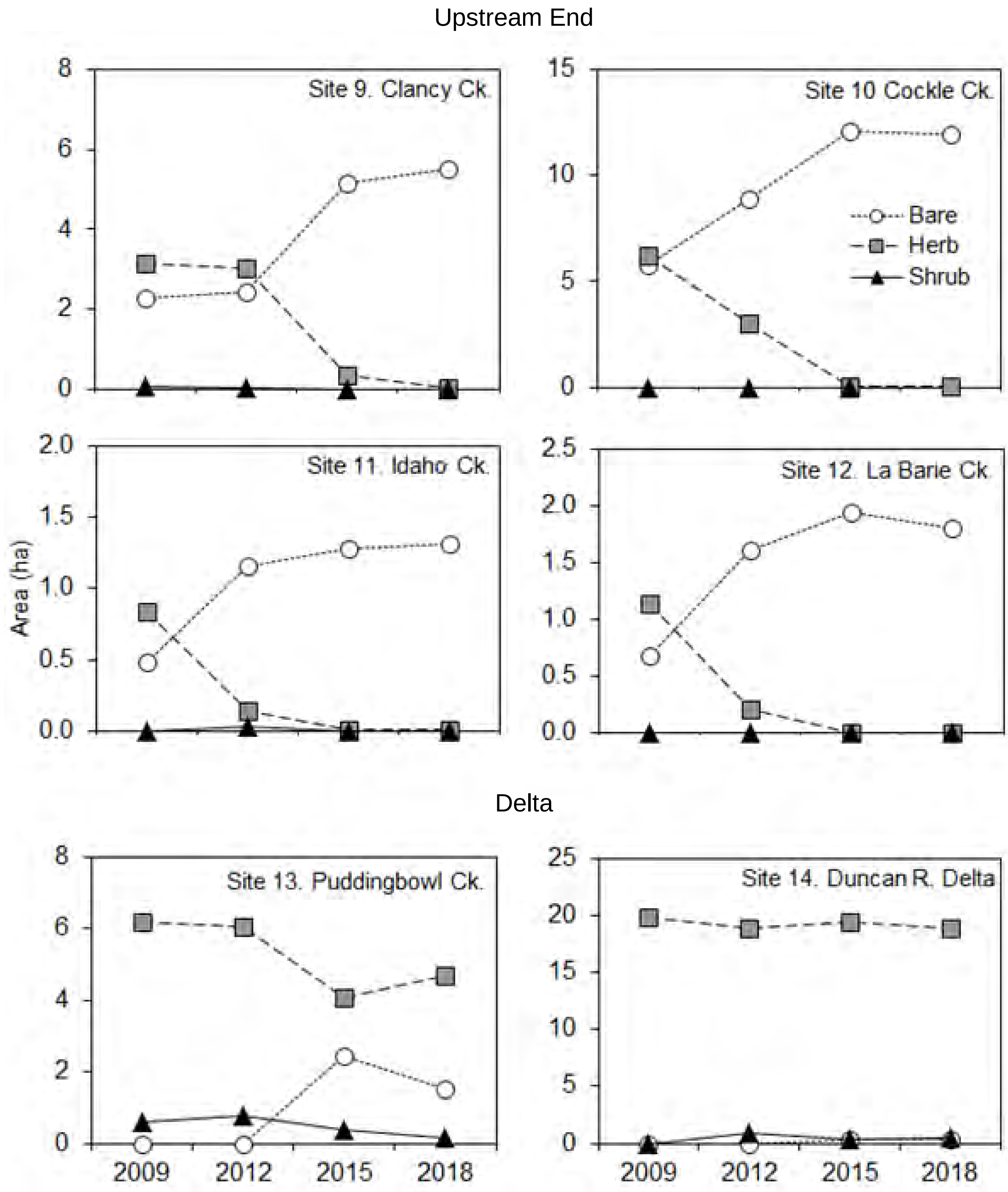


Figure 3-10: Total area (ha) for Sites 9 to 14 for Bare ground, Herbaceous, and Shrub cover for 2009, 2012, 2015, and 2018.

The gain in tree type area was the result of previous Shrub vegetation types transitioning into the Tree vegetation types. Please note that a Tree classification is woody vegetation greater than 2 m in height. Appendix 2 table shows the vegetation types and area for each Site for 2018 data and summaries for 2009 to 2015 data.

Bare ground increased across the four study years of the ten year period. Appendix 2 table shows the total increase in Bare ground for each study year but variations occurred at individual Sites for each sampling year. Figure 3-9 and Figure 3-10 show each site with total Herbaceous and Shrub Cover along with Bare ground (B1 and B2 combined). Site 1 does not show a marked increase in Bare ground until 2018 while Sites 2, 7, 9, and 13 show a marked increase starting in 2015. Sites 3, 10, 11, and 12 show a marked increase starting in 2012. The remaining sites show a gradual increase in Bare ground since 2009. Site 6 remained mainly bare ground from 2009 to 2018 (See page 72 for photo comparison) and Site 14 had minimal bare ground for the four study years.

Site 13 was an exception for all years with Bare ground never increasing in area size greater than vegetated area size (Figure 3-10). There was an increase in bare ground in 2015 which decreased in 2018 but not back to 2009 and 2012 levels.

The disturbance responsible for the Bare ground was not the reservoir fill regime but rather the result of overland flow by Puddingbowl Creek. In 2018, Puddingbowl Creek had established a deeper and more defined channel through the treed bench area before entering the open reservoir drawdown zone. This reduced, but did not eliminate, the overland flow across Site 13. Air photos of Site 13 in June 2015 and June 2018 show the recovering vegetation Cover over the Bare ground areas in 2015 (Figure 3-11).

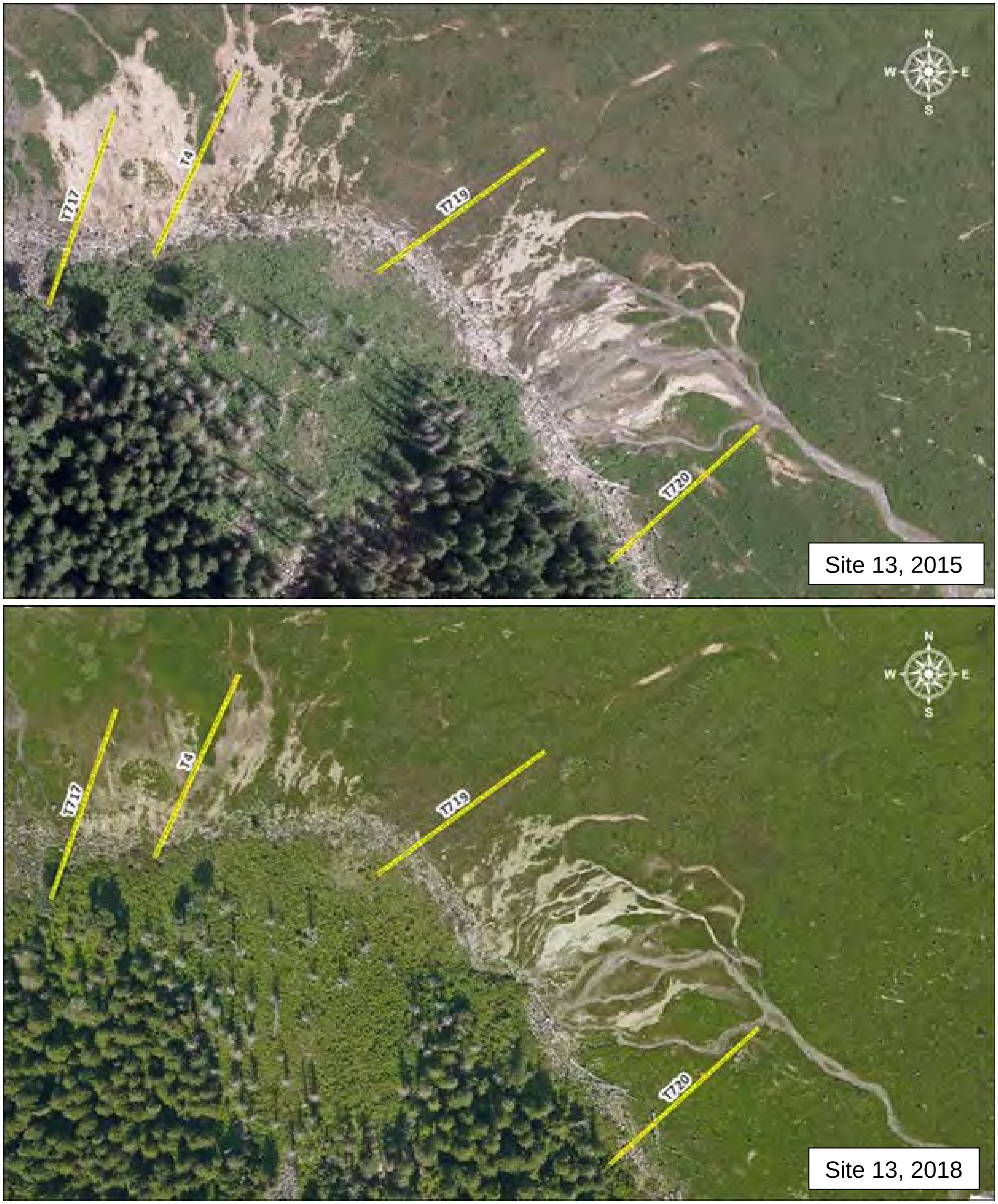


Figure 3-11: Air photos of Site 13 in June 2015 and in June 2018.

Community types

There have been changes in the community types based on the dominant species across years. Wetland communities and communities requiring wet open ground have decreased or have disappeared from the sampling sites. The communities within this type included (see Appendix 2 for the detailed table):

- H6, the small-flowered bulrush community, had an increase in size from 2009 to 2012 but then a steady decline in the area. The original area is no longer a bulrush community with horsetail as the third dominant species for the community. By 2018, the majority of the area is now common horsetail as the dominant species.
- H11, yellow monkey-flower has experienced a steady decline in the area from 3.52 ha in 2009 to 0.03 ha in 2018. This is an annual species, so it is strongly associated with seasonal weather patterns. The study years 2015 and 2018 both had warm dry spring conditions. H11 only occurred near seeps or small ephemeral streams that provided additional moisture.
- H2, sedge species as the dominant species, decreased to a trace amount of area by 2018. However, sedge species still contribute to communities as the second or third dominant species.
- H12, cottonwood less than 50 cm tall (measured within Herbaceous quadrats), had a small area (0.03 ha) close to full pool shorelines in 2009. It did not appear in any of the subsequent years of sampling. The area in the drawdown zone close to full pool is where woody debris collects at many of the sampling Sites. The areas that occurred in 2009 had the potential of loss of young woody vegetation through scouring by the woody debris.
- H1, common horsetail, is a Facultative (FAC) species that occur in wetlands or non-wetlands. It displayed a slight and steady decline since 2009. The H1 community was the dominant species along the drawdown zone for the reservoir in all sampling years. It remained considerably higher in cumulative cover and area covered over the four sampling years compared to other vegetation communities.

There were also four communities added after 2009. These were:

- H13, nodding wood-reed (added in 2012);
- H14, wormseed mustard (added in 2012);
- H15, mouse-eared chickweed (added in 2012); and
- H16, silvery hair-grass (added in 2015).

These four species occurred along the reservoir drawdown zone in 2009 but were not the dominant species for the community where they occurred. Nodding wood-reed (*Cinna latifolia*), a perennial grass, and the annual herbaceous species wormseed mustard (*Erysiumum cheiranthoides*) and mouse-eared chickweed (*Cerastium fontanum*) both weedy species, became dominant species for plant communities in 2012. In 2015, silvery hair-grass (*Aira caryophyllea*) was the dominant annual grass species, requiring the addition of the new community H16 to be added. Because there were no dominant grass communities in 2009, grass communities were combined in subsequent years to allow for comparison. The grass community H4 in 2009 covered 30.7 ha of the reservoir. The total area for combined grass communities (H4, H13, and H16) for each subsequent year was:

- 2012 = 7.0 ha;
- 2015 = 11.7 ha; and
- 2018 = 9.5 ha.

The 2009 grass community area was significantly larger than in 2012, 2015, and 2018 (data combined into H4 for all years for comparison) ($P = <0.001$, $t = -5.8$) (Appendix 4). Grass communities continued to be a dominant community type but did not cover as large of an area as in 2009.

The changes with these community types may have resulted from the spring weather more than the reservoir stage influence. The elevations sampled were exposed during the spring growing season when sampled in June. All species were present in 2009 but stressors such as low precipitation and warmer spring temperatures as in 2015 and 2018, may have promoted the expansion of silvery hair-grass. Nodding wood-reed may have increased with the higher precipitation in June 2012 allowing it to increase in cover from 2009.

Tree and shrub areas show variations across years. The tree area increased from 2015 mainly due to the transition of shrubs into the tree classification, as heights increased above two metres. The shrub areas showed a large increase to the area in 2012 and a large decrease in 2015 without a corresponding increase in the tree area. The 2012 air photos were taken before the reservoir filled above 576.7 m elevation (full pool). 2012 experienced above full pool levels during the summer to reduce flooding downstream of the drainage area. The result probably impacted the narrow zone close to full pool where shrubs occur. The 2015 air photo analysis showed increase area of bare ground due to woody debris at many of the sites. The woody debris may have scoured many of the smaller shrubs resulting in the reduced area in 2015.

Common horsetail is the dominant community for the reservoir for the four study years. Cover by the dominant community was graphed to explore the relationship with the bare ground that did not have trace vegetation (B1), Figure 3-12 (A). The horsetail community has a gradual decline from 2009 to 2018. The combined shrub community was also graphed in relationship to B1. The shrub community for the reservoir for each year had an increase in cover in 2012 but in 2015 it dropped below the 2009 area and recovered to 2009 level by 2018.

Figure 3-12 (B) shows Bare ground with trace vegetation (B2) which has less than 15 per cent vegetation cover, with most areas averaging less than 5 per cent cover with the ground truthing during vegetation surveys. Cover that did occur within the B2 area was dominated by small plants averaging 10 cm tall. The species included: mouse-eared chickweed, wormseed mustard, smart weed, and common horsetail.

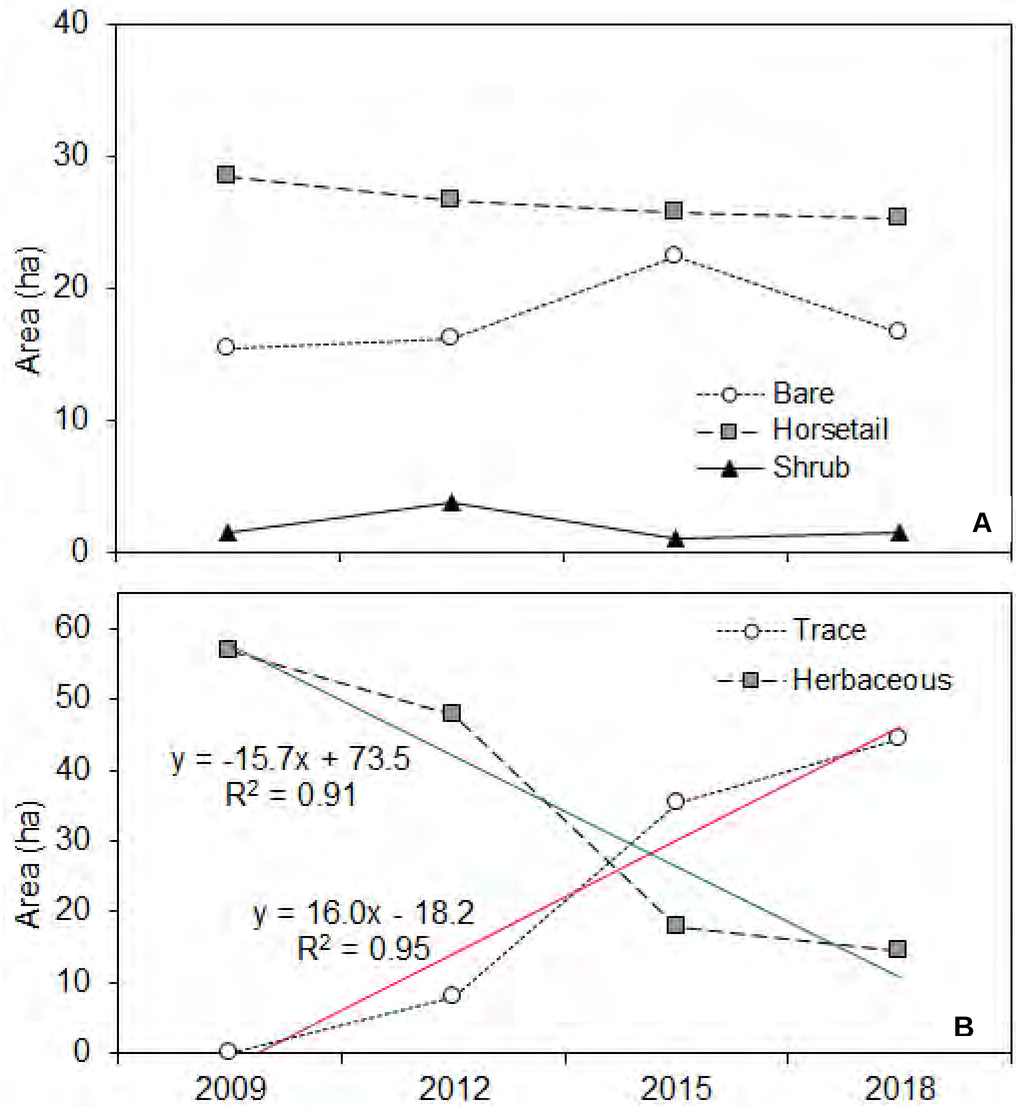


Figure 3-12: Bare ground (B1, no vegetation), horsetail, and the Shrub community for each study year (A). Bare ground with trace vegetation (B2) and Herbaceous communities combined for the four study years (B).

There was a progressive decrease in the vegetated area from 2009 to 2018, and conversely, an increase in Bare ground with trace vegetation (B2) (Figure 3-12). Both trends were highly significant, and reasonably represented with linear regression.

Combining both Bare ground classes and all vegetation (herbaceous, shrub, and tree) results in slightly lower R^2 values but the trends were still highly significant (Figure 3-13).

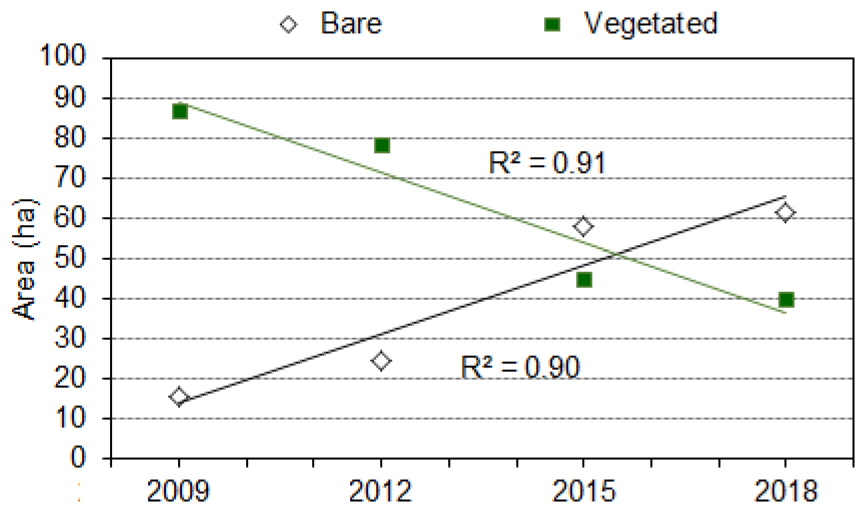


Figure 3-13: Comparison of the area of Bare (B1 and B2 combined) and vegetated ground cover for the reservoir (total area 102.6 ha) for 2009 to 2018 sampling years.

The statistical testing of areas for combined community types was completed, resulting in a significant difference across years for vegetation community changes. The differences in the median values among the years, 2009, 2012, 2015, and 2018 for bare ground (B1 and B2 combined), trees, shrubs, and herbaceous plant communities using all data, was greater than expected by chance with a statistically significant difference of P = 0.001. Isolation of the groups that differed showed that 2015 compared to 2018 had a P = 0.004. All other comparisons had a P >0.001 (Chi-square = 15.85 and P = 0.001) (Appendix 4).

Testing of the per cent of the area that was Bare indicated that 2015 and 2018 were significantly larger than 2009 (P = 0.02, t = 26.7) but the per cent of the Bare ground in 2012 was apparently larger than 2009 (Appendix 4). Assessment needs to be conservative as there were only four data points for the per cent of the area for Bare ground analysed. However, there has been a gradual increase of Bare ground with a trendline $R^2 = 0.9$. The per cent of the area covered by vegetation was the reverse as indicated in Figure 3-13 with a significant decrease in area for 2015 and 2018 compared to 2009 (P = 0.02, t = 26.8) but 2012 was not significantly smaller in the per cent of the area covered by vegetation communities compared to 2009 (Appendix 4).

The broad scale analysis revealed that the vegetated area decreased over the decade but whether this was due to Alt S73 is less certain. The ‘mechanistic’ analysis from the field inventory will help to refine the many factors influencing vegetation Cover and may indicate which factors could contribute to the reduction of vegetation Cover. Those field inventory results are presented in Section 3.3.2.

3.2.1 Ordination of Sites by Area

The NMS analysis of the vegetation communities by area was completed using all communities and all sites for the four years with the results graphed. Data failed the Monte Carlo test (P = 0.12 on axis 1, P = 0.06 on axis two and P = 0.04 on axis three) so it was not used for analysis but it is supplied in Appendix 3 as a visual aid to represent how communities shifted across years for all Sites and with all of the community types.

Data was then reduced (see methods for grouping vegetation communities and criteria used) resulting in data passing the Monte Carlo test Axis 1 – P = 0.04, and Axes 2, 3, and 4 of P = 0.02, with a 3-dimensional solution recommended (Appendix 4).

The coefficients of determination for the correlation between ordination distances and distances in the original n-dimensional space were:

- Axis 1 – R2 = 0.30;
- Axis 2 – R2 = 0.46; and
- Axis 3 – R2 = 0.57.

Even though axes 2 and 3 had the strongest correlation, axes 1 and 2 were chosen to be graphed because the herb community was associated strongly with axis 1 (Figure 3-14).

The second matrix had the community types grouped to show the influence of each vegetation type. These were: tree, shrub, and a total of the herbaceous communities (all communities from original list).

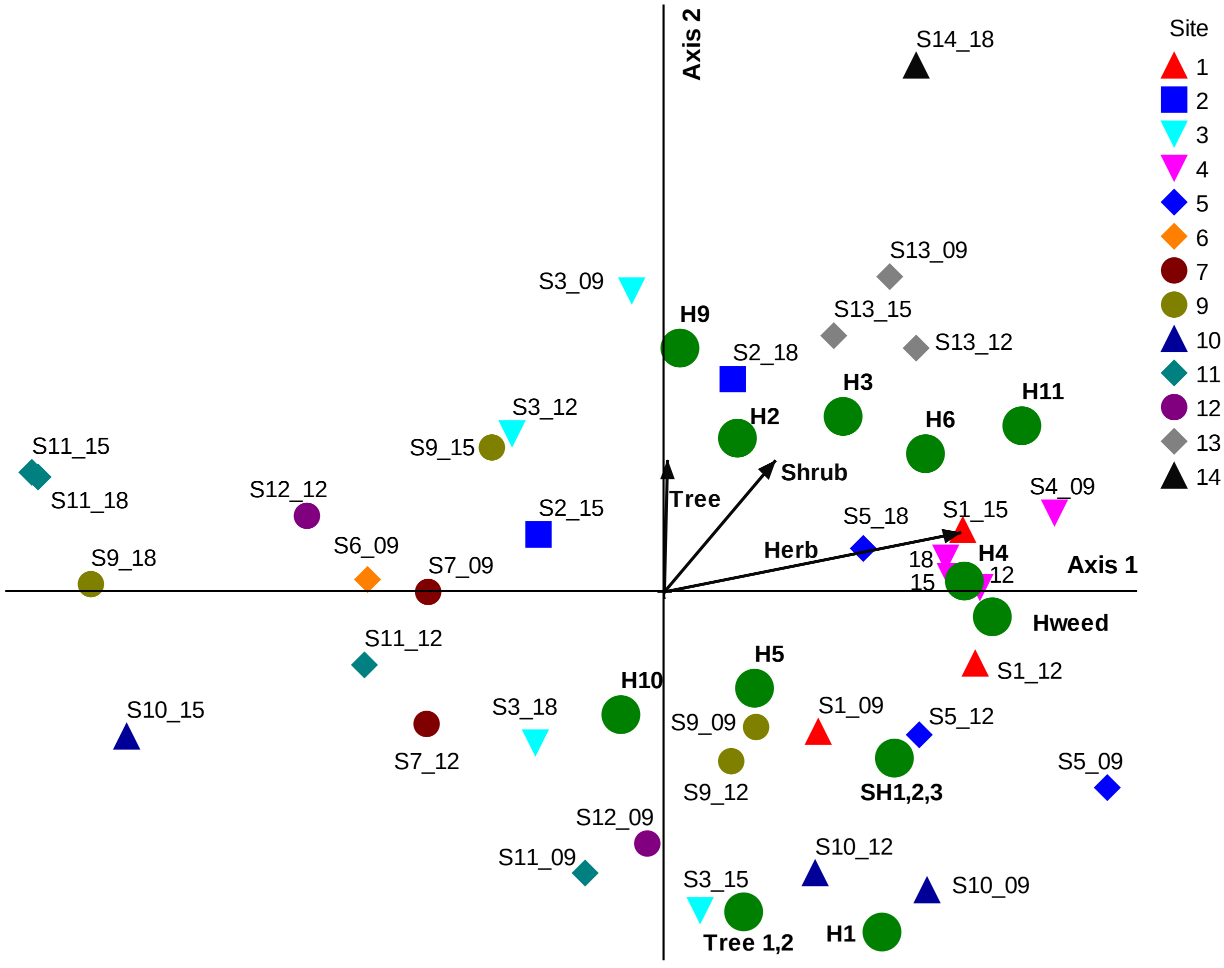


Figure 3-14: Nonmetric multidimensional scaling (NMS) applied to area occupied by the community for each site for each sampling year. The ordination is on rank order. The vectors indicate the direction of increasing cover, and their length reflects the magnitude of the association with ordination axes.

The vectors have a correlation with the ordination axes:

- Bare ground $R^2 = 0.05$ with axis 3;
- Shrub $R^2 = 0.25$ with axis 2;
- Tree $R^2 = 0.24$ with axis 2; and
- Herb $R^2 = 0.55$ with axis 1.

Because axes 1 and 2 were chosen for Figure 3-14 there is no ‘Bare’ vector because the $R^2 = 0.01$ for axis 1 and zero for axis 2.

Testing H_{01}

The testing of the H_{01}: “Alt S73 will not result in a decrease to the area and alterations in the species composition of both wetland and riparian vegetation communities” was completed using the Mantel test. The test for alterations in the species composition (change in vegetation communities) resulted in the rejection of the H_{01} with $P = 0.00$, $r = 0.36$ (r = Standardized Mantel statistic). A second test was completed for the bare ground which resulted in a significant increase in the bare ground area since 2009 (actual $P = 0.0009$, rounded off to $P<0.00$, $r = 0.16$) (Appendix 4). Therefore, the H_{01} was rejected as there was a decrease in area and alterations in the species composition for all vegetation communities including the riparian and wetland communities. This analysis supports the prior analyses, with the regression analysis revealing a progressive transition from trace vegetation to barren, as well as the χ^2 analysis that confirmed the significant changes across the four vegetation surveys.

3.3 Field Sampling

3.3.1 Ground level Photograph Monitoring Points

The information for the individual site with reservoir data is found in Table 3-1 to Table 3-12. Information about the tables is found in Methods, Section 2.3 Field Sampling

Ground Level Photo-Monitoring Points. The “W” prior to the species code name indicates weedy species (in tables) following Royer and Dickinson (1999) and species listed as weedy is from the *B.C Weed Control Act*.

Upland summary tables for each site include dominant species, cumulative cover, species richness, and site cover by upland for tree, shrub, and herb plots.

Site 1 was the most southern site and closest to the Duncan Dam. The sampled upland zone above full pool (Appendix 1 can be found in the developed Glacier Creek Forest Recreation Site. A summary of the Site 1 findings are located in Table 3-1.

Table 3-1: The dominant plant species, cumulative cover, species richness, and overall reservoir vegetation cover totals for Site 1, monitored in 2018. Site richness for 2009, 2012, 2015, and 2018 is included for comparison.

Dominant Species for Site 1	Cumulative Cover	Site Cover %	Reservoir cover %	Reservoir Dominant Species	Cumulative Cover
h_W_Equi_arv N)	173.2	11.9	1.6	h_W_Equi_arv (N)	3,870.8
h_W_Poly_lap (N)	170.6	11.8	1.5	h_Care_spp (N)	710.5
h_Coll_lin (N)	138.1	9.5	1.2	h_Moss (N)	660.1
h_Care_aqu (N)	90	6.2	0.8	h_Coll_lin (N)	412.4
h_W_Cera_vul (N)	80.2	5.5	0.7	h_W_Poly_lap (N)	338.6
h_W_Erys_che (N)	58.8	4.1	0.5		

Vegetation Type	Site Richness				Reservoir Richness	
	09	**12**	**15**	**18**		**Coding:** h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.
Herb	20	17	22	23	53	
Shrub	4	0	2	3	12	
Tree	5	3	4	4	7	
Total	29	20	28	30	72	

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 1. Upland transects lengths were: #1: 0-31 m, #869: 0-24 m. There was no change from 2015, except the growth of trees and shrubs.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Pseu_men	210.0	57.9	20.0	T = 7
	Lari_occ	55.0	15.2	95.5	
	Betu_pap	42.5	11.7	5.8	
	Pinu_con	30.1	8.3	100.0	
S 8 m^2	Rubu_par	32.5	56.3	19.1	S = 9
	Shep_can	17.5	30.3	6.9	
H 1 m^2	Pach_myr	37.5	24.0	42.9	H = 21
	Moss	17.5	11.2	2.3	
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 1 had two transect lines, Transect #1 and Transect #869.

Site 1 - Transect #1 (320 m)

2009 Looking up the line at 87 m.

2018 Looking up the line at 87 m.

Site 1 - Transect #869 (134 m)

2009 Looking down the line at 1 m.

2018 Looking down the line at 1 m.

Site 2 was located to the north and on the opposite side of Glacier Creek from Site 1. There is established recreational road access to the site. This area was frequently utilized by off road vehicles, as evidenced by the numerous tire tracks in the drawdown zone. Evening primrose (Oeno_vil) was the third dominant species in 2012 for the site, fell to fourth in 2015, and was ranked as the dominant species in 2018 (Table 3-2). It occurred mainly in one large patch along one transect line and occurred multiple times along transect #822. Reed canary grass (*Phalaris arundinacea*) is not listed as a noxious weed by the *B.C. Weed Control Act* but is a weedy species of concern and an invasive species prevalent in disturbed areas but not at the sites sampled at the Duncan Reservoir. In 2009, Site 2 had reed canary grass recorded along one transect line with a 2.5 per cent cover (1 m^2 quadrat). In 2015 and 2018 there was no reed canary grass observed along transects. Change in tag #s: 701 = 884, 702 = 885, and 703 = 822. Summaries are presented in Table 3-2.

Table 3-2: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 2 in 2018.

Dominant Species for Site 2	Cumulative Cover	Site Cover %	Reservoir cover %	Reservoir Dominant Species	Cumulative Cover
h_Oeno_vil (N)	260.0	19.3	2.3	h_W_Equi_arv (N)	3,870.8
h_Coll_lin (N)	193.2	14.3	1.7	h_Care_spp (N)	710.5
g_Agro_gig (E)	75.0	5.6	0.7	h_Moss (N)	660.1
g_Cinn_lat (N)	65.4	4.9	0.6	h_Coll_lin (N)	412.4
h_Lapp_red (N)	65.2	4.8	0.6	h_W_Poly_lap (N)	338.6
h_Care_aqu (N)	60.0	4.5	0.5		

Vegetation Type	Site Richness				Reservoir Richness
	09	12	15	18	
Herb	20	17	25	26	53
Shrub	4	0	2	4	12
Tree	5	3	3	3	7
Total	29	20	30	33	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 2. No changes were noted except for the growth of trees and shrubs. Upland transects lengths were: #884: 0-25 m, #885: 0-20 m, and #822: 0-24 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Popu_tri	260.0	45.4	41.6	T = 7
	Pseu_men	202.5	35.4	19.2	
	Betu_pap	75.1	13.1	10.3	
S 8 m^2	Amel_aln	32.5	28.8	92.6	S = 6
	Shep_can	15.2	13.5	6.0	
	Rubu_par	15.0	13.3	8.8	
H 1 m^2	Moss	85.0	46.4	11.3	H = 10
	Linn_bor	37.5	20.5	62.4	
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 2 - Transect #884 (304 m)

2009 Looking up the line at 163 m.

2018 Looking up the line at 163 m.

Site 2 –Transect #885 (388 m)

2009 Looking down the line at 6 m.

2018 Looking down the line at 1 m.

2009 Looking down reservoir at 31 m.

2018 Looking up the line at 61 m.

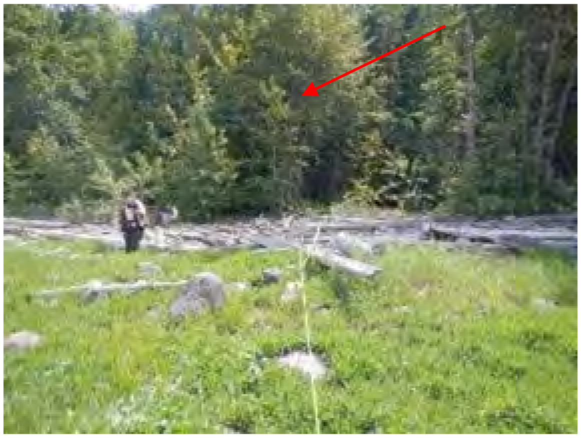
Site 2 –Transect #885 Continued

2009 Looking down reservoir at 44 m

2018 Looking up the line at 30 m.

Site 2 –Transect #822 (360 m)

2009 Looking up the line at 30 m.



2018 Looking up the line at 30 m.

Site 3 was located on a peninsula in an area referred to as the "Lower Arm", which occurs between Duncan Island and the eastern shore of Duncan Reservoir. No external influences were noted for this site. Reed canary grass was recorded along transect line 812 within one quadrat at 2.5 per cent cover of the 30 per cent cover for the one quadrat in 2015. There was no reed canary grass recorded along transects in 2018. By 2015 there was only a remnant of it surviving in the one location near full pool. By 2018, it was gone and the quadrat had a cover of 87.6 per cent of other herbaceous species less dependent on high moisture levels. Site 3 has a very shallow substrate over bedrock. See Table 3-3 for summaries of cover and species richness. Since a second transect line, #812, was added in 2012, the comparison photos are from 2012 and 2018.

Table 3-3: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 3 in 2018.

Dominant Species for Site 3	Cumulative Cover	Site Cover %	Reservoir cover %	Reservoir Dominant Species	Cumulative Cover
h_Moss (N)	380	55.6	3.4	h_W_Equi_arv (N)	3,870.8
h_W_Equi_arv (N)	150	22.0	1.4	h_Care_spp (N)	710.5
g_Cinn_lat (N)	72.5	10.6	0.7	h_Moss (N)	660.1
h_W_Cera_vul (N)	67.9	9.9	0.6	h_Coll_lin (N)	412.4
h_Coll_lin (N)	55.5	8.1	0.5	h_W_Poly_lap (N)	338.6

Vegetation Type	Site Richness				Reservoir Richness
	09	12	15	18	
Herb	20	17	19	14	53
Shrub	4	0	5	6	12
Tree	5	3	3	4	7
Total	29	20	30	24	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurred within a two-metre change in elevation above full pool for Site 3. No change was noted except for the growth of trees and shrubs. Upland transects lengths were: #704: 0-25 m and #812: 0-6 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Thuj_pli Pseu_men	207.5 140.0	55.0 37.1	11.2 13.3	T = 3
S 8 m^2	N/A	-	-	-	S = 6
H 1 m^2	Moss Pleu_sch	100.0 97.5	46.5 45.3	13.2 52.7	H = 7
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 3 – Transect #704 (52 m)

2012 Looking up the line at 17 m.

2018 Looking up the line at 17 m.

Site 3 – Transect #812 (48 m)

2012 Looking up the line at 48 m.

2018 Looking up the line at 48 m.

Site 4 was located on a long, narrow bay on the western side of a large island (Duncan Island). Duncan Island supports a private woodlot. A number of permanent, private residences are also located in the undisturbed upland above full pool. See Table 3-4 for cover and species richness summary.

Table 3-4: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 4 in 2018.

Dominant Species for Site 4	Cumulative Cover	Site Cover %	Reservoir cover %	Reservoir Dominant Species	Cumulative Cover
h_W_Equi_arv (N)	277.6	38.0	2.5	h_W_Equi_arv (N)	3870.8
h_Moss (N)	122.5	16.8	1.1	h_Care_spp (N)	710.5
h_Mimu_gut (N)	85.2	11.7	0.8	h_Moss (N)	660.1
g_Aira_car (E)	65.4	9.0	0.6	h_Coll_lin (N)	412.4
h_W_Cera_vul (N)	35.3	4.8	0.3	h_W_Poly_lap (N)	338.6
h_W_Medi_lup (E)	30.1	4.1	0.3		

Vegetation Type	Site Richness				Reservoir Richness
	09	12	15	18	
Herb	20	17	17	18	53
Shrub	4	0	1	2	12
Tree	5	3	2	2	7
Total	29	20	20	22	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 4. No changes noted except for the growth of trees and shrubs. Upland transects lengths were: #705: 0-12 m and #706: 0-6 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	T_Thuj_pli	185.0	60.7	9.9	T = 3
	T_Pseu_men	67.5	22.1	6.4	
	T_Betu_pap	52.5	17.2	7.2	
S 8 m^2	Shep_can	62.5	56.8	24.7	S = 2
	Thuj_pli	30.0	27.3	46.1	
H 1 m^2	Moss	85.0	79.1	75.0	H = 4
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 4 – Transect #705 (71 m)

2009 Looking up the line at 50 m.

2018 Looking up the line at 50 m.

Site 4 – Transect #706 (54.0 m)

2009 Looking up the line at 51 m.

2018 Looking up the line at 51 m.

Site 5 was located in an area referred to as the "Upper Arm", which occurs between Duncan Island and the eastern shore of the Duncan Reservoir. There was little evidence of recent human activity in the upland, since access to the site had substantial brush cover in a previously logged area and required "bushwhacking". Well used game trails were observed and noted during site access. In past surveys, there was no observable influence of the creek flow, but there were large quantities of water seeping from the upland, forming extensive saturated areas that did not support vegetation. In 2018, there was substantial drying of the site that started in 2015. See Table 3-5 for cover and species richness summaries.

Table 3-5: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 5 in 2018.

Dominant Species for Site 5	Cumulative Cover	Site Cover %	Reservoir cover %	Reservoir Dominant Species	Cumulative Cover
h_W_Equi_arv (N)	117.7	10.4	1.1	h_W_Equi_arv (N)	3870.8
g_Aira_car (E)	115.6	10.2	1.0	h_Care_spp (N)	710.5
h_Mimu_gut (N)	47.5	4.2	0.4	h_Moss (N)	660.1
g_Cinn_lat (N)	22.5	2.0	0.2	h_Coll_lin (N)	412.4
h_W_Erys_che N)	20.4	1.8	0.2	h_W_Poly_lap (N)	338.6
h_W_Matr_dis (E)	20.3	1.8	0.2		

Vegetation Type	Site Richness				Reservoir Richness
	09	12	15	18	
Herb	20	17	16	13	53
Shrub	4	0	2	5	12
Tree	5	3	1	1	7
Total	29	20	19	19	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 5. No change noted except for growth of tree and shrubs. Upland transects lengths were: #707: 0-10 m and #813: 0-12 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Thuj_pli	330.0	44.6	17.7	T = 5
	Tsug_het	152.5	20.6	18.8	
	Betu_pap	140.0	18.9	19.1	
S 8 m^2	Shep_can	122.5	72.1	48.5	S = 5
	Rubu_par	42.5	25.0	25.0	
H 1 m^2	Moss	15.0	35.2	2.0	H = 6
	Pter_aqu	15.0	35.2	37.4	
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 5 – Transect #707 (130 m)

2009 Looking up the line at 106 m.

2018 Looking up the line at 106 m.

Site 5 – Transect #813 (71 m)

2012 Looking up the line at 48 m.

2018 Looking up the line at 48 m.

Site 6 was located on the southern side of "Little Glacier Creek". This site was influenced by the creek and proximity to the Duncan River Forest Service Road. An overgrown skid trail and an abandoned camper indicated that this area was regularly visited by people prior to 2008. Vegetation on the site was sparse with the majority of the transect line on bare ground (Table 3-6). There were 6 species at the site and all of them had an observed frequency of one, i.e., occurring in a single quadrat. Two quadrats had vegetation recorded for each transect. No dominant species was observed, but the two species that occurred once in a quadrat with a cover of 15 per cent are listed as the dominant species. Since transect #814 was added in 2012 the photo comparisons are 2012 to 2018.

Table 3-6: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 6 in 2018.

Dominant Species for Site 6	Cumulative Cover	Site Cover %	Reservoir Cover %	Reservoir Dominant Species	Cumulative Cover
h_W_Poly_lap (N)	15	59.3	0.14	h_W_Equi_arv (N)	3870.8
t_Thuj_pli S_ (N)	15	59.3	0.14	h_Care_spp (N)	710.5
				h_Moss (N)	660.1
				h_Coll_lin (N)	412.4
				h_W_Poly_lap (N)	338.6

Vegetation Type	Site Richness				Reservoir Richness
	09	12	15	18	
Herb	20	17	5	5	53
Shrub	4	0	0	0	12
Tree	5	3	0	1	7
Total	29	20	5	6	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 6. In 2018, Transect Line #708 was reduced in length because of scouring from Little Glacier Creek. Transect Line #814 had reduced ground cover because of the bank slide which removed vegetation in 2015 and created an extremely steep bank. There was sparse herbaceous growth at the toe of the bank but no colonization of the steep bank by 2018. Upland transects were: #708: 0-27 m and #814: 0-5 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Tsug_het	177.5	35.1	21.8	T = 5
	Thuj_pli	160.0	31.7	8.6	
S 8 m^2	Shep_can	17.5	33.3	6.9	S = 2
	Tsug_het	17.5	33.3	87.5	
H 1 m^2	Pleu_sch	85.0	55.7	45.9	H = 2
	Moss	67.5	44.3	8.9	
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 6 - Transect #708 (128 m)

2009 Looking up the line at 38 m.

2018 Looking up the line at 38 m.

Site 6 - Transect #814 (35 m)

2012 Looking up the line at 36 m.

2018 Looking up the line at 36 m.

2012 Looking down the line at 1 m.

2018 Looking down the line at 1 m.

Site 7 was located on a point of land defined by Howser Creek to the north and the Duncan Reservoir to the west. A well-used camp site was located in the upland above the full pool. Although Howser Creek was adjacent to the site, there was no observable creek influence on the site. See Table 3-7 for cover and species richness summaries.

Table 3-7: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 7 in 2018.

Dominant Species for Site 7	Cumulative Cover	Site Cover %	Reservoir Cover %	Reservoir Dominant Species	Cumulative Cover
h_W_Cent_mac E)	32.6	24.0	0.3	h_W_Equi_arv (N)	3,870.8
h_Frag_vir (N)	15	11.1	0.1	h_Care_spp (N)	710.5
				h_Moss (N)	660.1
				h_Coll_lin (N)	412.4
				h_W_Poly_lap (N)	338.6

Vegetation Type	Site Richness				Reservoir Richness	
	09	**12**	**15**	**18**		**Coding:** h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.
Herb	20	17	6	6	53	
Shrub	4	0	0	1	12	
Tree	5	3	1	1	7	
Total	29	20	7	8	72	

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 7. Transect #3 had brush and trees (cut down along the full pool edge – human impact in 2012) that were growing back since the clearing. No changes noted except for the growth of trees and shrubs for both transects. Upland transects lengths were: #2: 0-24 m and #3: 0-7 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Popu_tre	65.0	20.1	78.8	T = 8
	Betu_pap	62.5	19.4	8.5	
	Popu_tri	55.0	17.0	8.8	
	Corn_sto	52.6	16.3	20.0	
	Pinu_mon	52.5	16.3	99.8	
S 8 m^2	Rosa_gym	62.6	44.7	96.2	S = 4
	Corn_sto	37.5	26.7	99.7	
	Popu_tri	20.0	14.3	21.6	
H 1 m^2	Cent_mac	275.0	45.0	88.0	H = 11
	Moss	152.5	25.0	20.2	
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 7 consisted of two transect lines: Transect #2 and Transect #3.

Site 7 - Transect #2 (40 m)

2009 Looking up the line at 28 m.

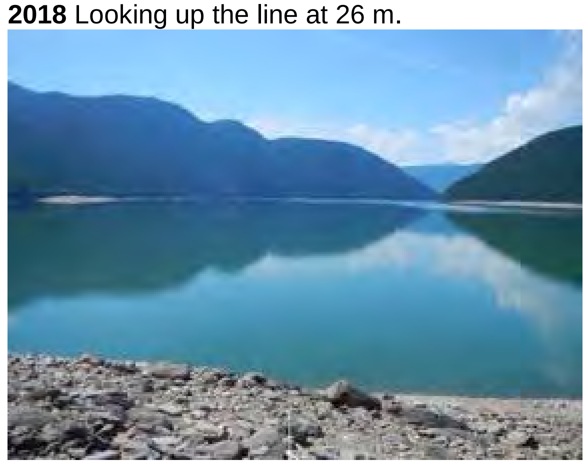
2018 Looking up the line at 28 m.

Site 7 - Transect #3 (55 m)

2009 Looking up the line at 28 m.

2018 Looking up the line at 26 m.

2009 Looking down line at 28 m.



2018 Looking down the line at 26 m.

Site 9 was located on the north side of Clancy Creek. An unofficial camp site was located on the south side of the creek in the upland above full pool and was accessed by an old road. Although Clancy Creek was nearby, no observable creek influence was noted on the site itself. See Table 3-8 for cover and species richness summaries.

Table 3-8: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 9 in 2018.

Dominant Species for Site 9	Cumulative Cover	Site Cover %	Reservoir Cover %	Reservoir Dominant Species	Cumulative Cover
h_Care_spp (N)	217.5	18.3	2.0	h_W_Equi_arv (N)	3,870.8
h_W_Equi_arv (N)	166.4	14.0	1.5	h_Care_spp (N)	710.5
h_W_Poly_lap (N)	56.3	4.7	0.5	h_Moss (N)	660.1
h_Linn_bor (N)	15	1.3	0.1	h_Coll_lin (N)	412.4
h_Equi_hye (N)	12.5	1.0	0.1	h_W_Poly_lap (N)	338.6
h_W_Chen_alb (N)	7.5	0.6	0.1		

Vegetation Type	Site Richness				Reservoir Richness
	09	**12**	**15**	**18**	
Herb	20	17	9	11	53
Shrub	4	0	3	3	12
Tree	5	3	0	0	7
Total	29	20	12	14	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 9. No changes were noted except for the growth of trees and shrubs. Upland transect line lengths were: #709: 0-7 m, #710: 0-13.5 m, #711: 0-14 m, and #712: 0-13 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Thuj_pli Betu_pap	475.0 180.0	52.8 20.0	25.5 24.6	T = 9
S 8 m^2	Pach_myr	77.5	83.7	83.8	S = 5
H 1 m^2	Moss	102.5	95.2	13.6	H = 3
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 9 -Transect #709 (92 m)

2009 Looking up the line at 56 m.

2018 Looking up the line at 56 m.

Site 9 - Transect #710 (107 m)

2009 Looking up the line at 14 m.

2018 Looking up the line at 14 m.

2009 Looking down the line at 14 m.

2018 Looking down the line at 14 m.

Site 9 - Transect #711 (151 m)

2009 Looking up the line at 45 m.

2018 Looking up the line at 45 m.

Site 9 - Transect #712 (168 m)

2009 Looking up the line at 39 m.

2018 Looking up the line at 39 m.

Site 10 was located on both the north and south sides of Cockle Creek, although none of the transect lines intercepted the creek. An unofficial camp site was located on the north side of the creek in the upland above full pool and was accessed by an old road, which ended at the reservoir, but did not cross the creek. Cockle Creek, which intersected the site, influenced the upland section of Transect #6. Transects #713 and #714 were not affected. See Table 3-9 for cover and species richness summaries.

Table 3-9: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 10 in 2018.

Dominant Species for Site 10	Cumulative Cover	Site Cover %	Reservoir Cover %	Reservoir Dominant Species	Cumulative Cover
h_Care_spp (N)	40.1	6.0	0.4	h_W_Equi_arv (N)	3,870.8
h_Drya_dru (N)	40	6.0	0.4	h_Care_spp (N)	710.5
h_W_Equi_arv (N)	27.7	4.1	0.3	h_Moss (N)	660.1
h_W_Cent_mac (E)	15	2.2	0.1	h_Coll_lin (N)	412.4
h_W_Rume_cri (E)	15	2.2	0.1	h_W_Poly_lap (N)	338.6
h_W_Poly_lap (N)	14	2.1	0.1		

Vegetation Type	Site Richness				Reservoir Richness
	09	12	15	18	
Herb	20	17	15	16	53
Shrub	4	0	2	1	12
Tree	5	3	2	1	7
Total	29	20	19	18	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 10. The last 5 m of Transect #6 was impacted by scouring from Cockle Creek and had very low vegetation cover to no cover along this section of the line compared to previous years. No change was noted except for the growth of trees and shrubs for the other two lines. Upland transects line lengths were: #713: 0-14 m, #714: 0-11 m, and #6: 0-24 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Pseu_men	185.0	27.6	17.6	T = 7
	Tsug_het	140.0	20.9	17.2	
	Thuj_pli	117.6	17.5	6.3	
	Pice_gla	102.5	15.3	95.3	
S 8 m^2	Popu_tri	52.5	65.5	56.8	S = 3
H 1 m^2	Pach_myr	42.5	27.3	48.6	H = 9
	Cent_mac	32.6	21.0	10.4	
	Moss	30.0	19.3	4.0	
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 10 - Transect #6 (185 m)

2009 Looking up the line at 85 m.

2018 Looking up the line at 71 m.

Site 10 - Transect #713 (90 m)

2009 Looking up the line at 52 m.

2018 Looking up the line at 52 m.

Site 10 - Transect #714 (84 m)

2009 Looking down the line at 1 m.

2018 Looking down the line at 1 m.

Site 11 was located on the west side of Duncan Reservoir and was accessible by a new road in 2018. The site spanned the north and south sides of Idaho Creek; with transect line #716 intercepting the creek. Idaho Creek, which intersected the site, was noted as an influence on the northernmost transect (#716), but not on the southernmost transect (#715). Reed canary grass was recorded along transect 715 within four different quadrats with 15 per cent cover within each of the three quadrats and 2.5 per cent in the fourth quadrat (total cumulative cover of 47.5 per cent cover) and transect 716 had one quadrat with 2.5 per cent cover in 2009. In 2012 cover was reduced to 0.1 per cent within the four quadrats and two quadrats with 2.5 per cent each for transect 716. In 2015, reed canary grass was reduced to 2.5 per cent within a single quadrat, along transect 716. In 2018, no reed canary grass occurred along transects 715 or 716 quadrats. The quadrats at Site 11 with reed canary grass occurred at lower elevations than at Site 3. It is theorized that the annual fill regime resulted in inundation durations long enough to reduce and eliminate the reed canary grass sampled since 2009 by 2018. See Table 3-10 for cover and species richness summaries.

Table 3-10: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 11 in 2018.

Dominant Species for Site 11	Cumulative Cover	Site Cover %	Reservoir Cover %	Reservoir Dominant Species	Cumulative Cover
h_W_Equi_arv (N)	240	47.9	2.2	h_W_Equi_arv (N)	3,870.8
h_Moss (N)	75	15.0	0.7	h_Care_spp (N)	710.5
h_Care_spp (N)	32.5	6.5	0.3	h_Moss (N)	660.1
g_Agro_gig (E)	30.1	6.0	0.3	h_Coll_lin (N)	412.4
g_Cinn_lat (N)	5.1	1.0	0.0	h_W_Poly_lap (N)	338.6

Vegetation Type	Site Richness				Reservoir Richness
	09	12	15	18	
Herb	20	17	7	6	53
Shrub	4	0	1	0	12
Tree	5	3	1	2	7
Total	29	20	9	8	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 11. Transect Line 716 had dead shrubs and small trees in 2018 that were alive and healthy in 2012 and 2015. The new road, which was uphill from the site, impacted the upland transects as clearing and road debris occurred within one metre of change in elevation. Blow downs from the road clearing and decrease in crown closure influenced the upland transects. Upland transect lengths were: #715 – 0-7 m and #716 – 0-7 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Thuj_pli	100.0	42.6	5.4	T = 5
	Acer_gla	65.0	27.7	55.3	
	Corn_sto	52.5	22.3	20.0	
S 8 m^2	Ribe_lac	62.5	44.6	100.0	S = 4
	Rubu_par	62.5	44.6	36.7	
H 1 m^2	Gymn_dry	15.0	85.2	99.3	H = 3
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 11 - Transect #715 (67 m)

2009 Looking down the line at 14 m.

2018 Looking down the line at 14 m.

2009 Looking up the line at 14 m.

2018 Looking up the line at 14 m.

Site 11 - Transect #716 (71 m)

2009 Looking down reservoir at 27 m.

2018 Looking down reservoir at 27 m.

2009 Looking down the line at 27 m.

2018 Looking down the line at 27 m.

Site 12 was located on the west side of Duncan Reservoir, immediately south of La Barie Creek, and was accessible by the new road in 2018. La Barie Creek runs through the north end of the site and had no influence on either transect (#5 or #718). See Table 3-11 for cover and species richness summaries.

Table 3-11: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 12 in 2018.

Dominant Species for Site 12	Cumulative Cover	Site Cover %	Reservoir Cover %	Reservoir Dominant Species	Cumulative Cover
h_W_Poly_lap (N)	23.6	18.3	0.2	h_W_Equi_arv (N)	3,870.8
h_W_Erys_che (N)	17.5	13.6	0.2	h_Care_spp (N)	710.5
h_Linn_bor (N)	15	11.7	0.1	h_Moss (N)	660.1
h_Care_spp (N)	7.7	6.0	0.1	h_Coll_lin (N)	412.4
h_W_Equi_arv (N)	2.5	1.9	0.0	h_W_Poly_lap (N)	338.6

Vegetation Type	Site Richness				Reservoir Richness
	09	12	15	18	
Herb	20	17	8	7	53
Shrub	4	0	0	0	12
Tree	5	3	0	0	7
Total	29	20	8	7	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

The following summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 12. Changes from road construction above the site influenced the upland transect. Upland transect lengths were: #718: 0-7 m and #5: 0-12 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Thuj_pli	135.0	51.4	7.3	T = 5
	Tsug_het	75.0	28.6	9.2	
S 8 m^2	N/A	-	-	-	S = 2
H 1 m^2	Moss	15.0	30.0	2.0	H = 4
	Pter_aqu	15.0	30.0	37.4	
	Vacc_mem	15.0	30.0	100.0	
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 12 - Transect #5 (60 m)

2009 Looking up the line at 45 m.

2018 Looking up the line at 45 m.

2009 Looking down the line at 45 m.

2018 Looking down the line at 45 m.

Site 12 - Transect #718 (52 m)

2009 Looking down the line at 1 m.

2018 Looking down the line at 1 m.

Site 13 was located on the west side of Duncan Reservoir at the extreme north end, near the confluence of Puddingbowl Creek and the Reservoir. The site was accessible by foot via a small, maintained path, which was used to access camp sites situated in the upland from 2009 to 2015. The new road cut across the hill high above the site. Bushwhacking from the edge of the road came out onto the original trail about 15 minutes from the site. Puddingbowl Creek intersected the site and was noted as an influence on all surveyed transects, since its channel was extremely braided and changed channels and overland flow each of the sampling years. The ground within the area of Site 13 had a gradual slope (average of 3.7 per cent) and did not meet the 10 m change in elevation requirement for a reasonable transect length. A transect line in excess of possibly 1 km would have been needed to fulfill the 10 m change in elevation criteria. The full pool edge scour that was easily identified for all other Sites did not occur at Site 13. This made it difficult to decide where transects should start in 2009. During our second visit, in 2012, it was determined that transect lines 717, 719, and 720 started above full pool. In 2018 this was confirmed using drone photos taken July 30, when the reservoir level at the dam was 576.3 m.

Reed canary grass occurred within one quadrat with a 2.5 per cent cover in 2012. No reed canary grass was recorded along any of the transect lines in 2009, 2015, and 2018. Where the reed canary grass was recorded willow had colonize the area and probably shaded out the reed canary grass. The sections of transects that were determined to be upland were removed from the drawdown data for all years of the study for 2018 analyses. See Table 3-12 for cover and species richness summaries.

Willow species were not one of the dominant covers in 2009 or 2018. However, change did occur at Site 13 since 2009. Willow species combined total cover measured within Herb quadrats (seedlings) was 2.5 per cent in 2009 and in 2018 it was 15 per cent total cover. Willow species measured within Shrub plots (<2 m tall) total cover for the 4 transects combined was 115 per cent in 2009 and 290 per cent in 2018.

Willow species combined total cover at Site 13 contributed 45.2 per cent of the total shrub cover for the reservoir in 2009. In 2018, shrub cover at Site 13 contributed 68.5 per cent of the total reservoir cover.

Table 3-12: The dominant species, cumulative cover, species richness, and overall reservoir totals for Site 13 in 2018.

Dominant Species for Site 13	Cumulative Cover	Site Cover %	Reservoir Cover %	Reservoir Dominant Species	Cumulative Cover
h_W_Equi_arv (N)	2192.7	71.4	19.8	h_W_Equi_arv (N)	3,870.8
h_Care_spp (N)	127.9	4.2	1.2	h_Care_spp (N)	710.5
g_W_Poa_pra (E)	110.0	3.6	1.0	h_Moss (N)	660.1
g_Cinn_lat (N)	92.6	3.0	0.8	h_Coll_lin (N)	412.4
h_Moss (N)	52.5	1.7	0.5	h_W_Poly_lap (N)	338.6
h_Equi_hye (N)	35.3	1.1	0.3		

Vegetation Type	Site Richness				Reservoir Richness
	09	12	15	18	
Herb	20	17	15	9	53
Shrub	4	0	6	3	12
Tree	5	3	2	0	7
Total	29	20	23	12	72

Coding: h = herb, g = grass, W = weed, s = shrub, t = tree, (N) = native, (E) = exotic. All species names are located in Appendix 1 and species codes are the first 4 letters of the genus and first 3 letters of species.

Note: Species Richness is the number of species recorded for the vegetation type and is provided by Site and for the reservoir overall.

This summary is for the upland vegetation above full pool that occurs within a two-metre change in elevation above full pool for Site 13. Transect Line 719 had numerous dead tree stems in 2009 and most were still standing in the upland in 2012. All of the smaller tree stems closest to the reservoir full pool edge were absent in 2015. The young tree on the edge of the standing dead had the Transect tag put on in it in 2009. It was still there in 2012 but was gone by 2015. No changes were noted except for the growth of trees and mainly willow shrubs in the upland. Upland transects lengths were: #717: 0-13 m, #719: 0-20 m, #720: 0-11 m, and #4: 0-13 m.

Quadrat Area	Dominant Site Species	Cumulative Cover (%)	% Cover of Site	Site Cover by Res. Cov. (%)	Species Richness (#)
T 50 m^2	Sali_spp	342.5	33.3	91.7	T = 7
S 8 m^2	Sali_spp Popu_tri	62.5 15.0	69.4 16.7	96.2 16.2	S = 4
H 1 m^2	Moss	85.0	75.2	11.3	H = 7
Upland Species for Reservoir = 66 - Tree = 11 Shrub = 22 Herb = 33					

Note: Species richness column is the species found within each quadrat size sampling unit on each site.

Site 13 was the only Site that had a riparian community next to the reservoir full pool edge. The rest of the Sites along the reservoir had the edge of the reservoir go immediately into the upland hillside. Shrub species (can be recorded within Shrub and/or Tree quadrats) included three species of willow, red-osier dogwood, alder, and devil's club. The tree species included paper birch, spruce hybrid, black cottonwood, western redcedar, and western hemlock. The upland monitoring started in 2012, so photo comparison is 2018 photos compared to 2012 photos. These are supplied after the drawdown photo point comparisons.

Site 13 - Transect #717 (100 m)

2009 Looking up the line at 54 m.

2018 Looking up the line at 54 m.

2009 Looking down the line at 54 m.

2018 Looking down the line at 54 m.

Site 13 - Transect #719 (100 m)

2009 Looking up the line at 56 m.

2018 Looking up the line at 56 m.

2009 Looking down the line at 56 m.

2018 Looking down the line at 56 m.

Site 13 - Transect #720 (100 m)

2009 Looking up the line at 34 m.

2018 Looking up the line at 34 m.

2009 Looking down the line at 34 m.

2018 Looking down the line at 34 m.

Site 13 - Transect #4 (100 m)

2009 Looking up the line at 47 m.

2018 Looking up the line at 47 m.

2009 Looking down the line at 47 m.

2018 Looking down the line at 47 m.

Two examples of growth in the upland zone at Site 13 are presented below. Site 13 Transect #4 upland photo comparison has the spruce tree pointed out in the 2012 photo. The same tree has an arrow pointing to it in the 2018 photo. The tree has grown since 2012 but the willow has surpassed it making it hard to see the tree.

The second example is for the upland Site 13 Transect #717. The first drawdown photo shows the growth of the upland riparian vegetation taken from the 54 m mark looking at the POC, but it is hard to see. The 2012 and 2018 upland photos were taken from standing on a large tree that was down and approximately 1.5 m above the ground. The 2012 photo is standing close to the 0 m (POC) looking up the line into the tree plot area. The red-osier dogwood was an average height of 2.5 m and mountain alder averaged 3.0 m height. The 2018 photo, standing at the same place as the 2012 photo, shows dense red-osier dogwood averaging 4.5 m tall and obscuring the sight of the tree plot. A second photo from 2018 is past the western hemlock in the 2012 photo looking into the upland on the up-reservoir side (sampling is on the down reservoir side of transect). The mountain alder averaged 5.0 m tall within the tree plot in 2018.

Site 13 Upland - Transect #4 (20 m)

2012 Looking into drawdown zone within upland.

2018 Looking into upland at 15 m in drawdown.

Site 13 - Transect #717 (15 m)

2009 Looking into the tree plot at 0 m.

2018 Looking into the tree plot at 0 m

2018 Looking up reservoir at 7 m.

3.3.2 Vegetation Richness and Cover

Two vegetation characteristics were used to address the two study hypotheses; these were total vegetation Cover (abundance) and species Richness the number of species. Three main environmental factors were identified that affected vegetation: Site, Elevation, and Substrate.

3.3.3 Overall Reservoir

As displayed, the total vegetation Cover from all of the repetitive quadrats decreased by about one-half from 2009 to 2012 and then gradually decreased further in 2015 and 2018 (Figure 3-15) ($P < 0.00$, $H = 1089$). The vegetation sampled within the 1 m x 1 m Herb quadrat followed a similar pattern with a significant decrease in Cover after 2009 ($P < 0.00$, $H = 327$). There were far fewer 2 m x 5 m Shrub quadrats which did not display a significant change in Cover, over the decade interval ($P = 0.138$ $H = 5.51$). The 5 m x 10 m Tree quadrats were limited to the band near the full pool shoreline (between full pool (576.7 m) and 575.7 m) and displayed increasing cover over the interval ($P = 0.004$, $H = 13.34$), probably due to the growth of the established trees. Alt S73 regime held full pool or near full pool levels more consistently compared to the previous regime. This resulted in a decrease in herbaceous cover but did not change shrub cover significantly and benefited the established trees at the elevation band up to 1 m decrease in elevation from full pool. This band is also the area with the longest exposure period.

Figure 3-15 provides a histogram presentation and these values could also be plotted as points and linear regressions demonstrating the same, highly significant patterns:

- Total Cover – $R^2 = 0.74$, $y = -2.52x + 5,088$;
- Herb Cover – $R^2 = 76$, $y = -2.63x + 5,309$;
- Shrub Cover – $R^2 = 0.08$ (not significant), $y = -0.04x + 75$; and
- Tree Cover – $R^2 = 0.99$, $y = 0.14x – 287$.

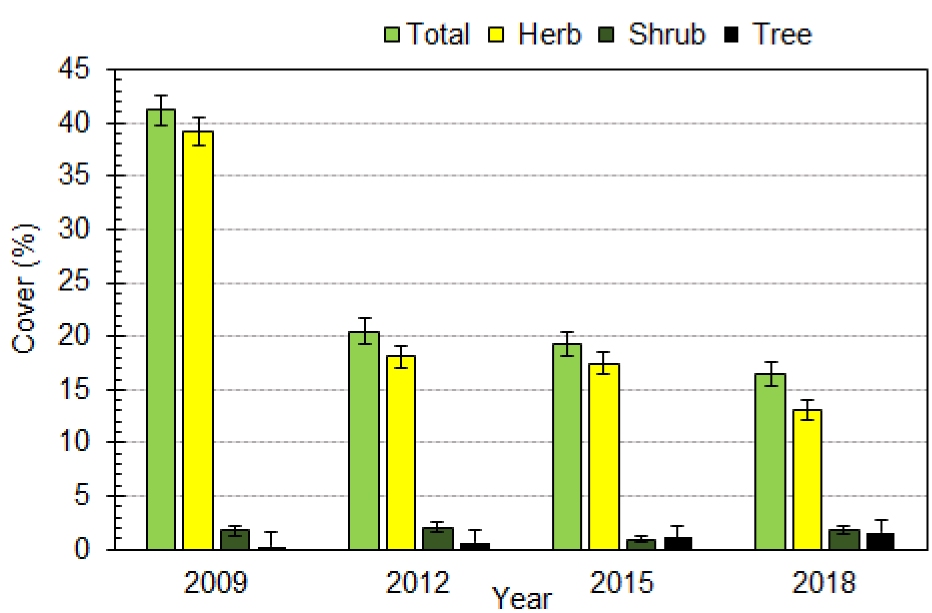


Figure 3-15: Mean (± s.e.) Total, Herb, Shrub, and Tree quadrat Cover for all of the reservoir sites combined, across the four sampling years

Species Richness provides the second vegetation measure, and this was quite consistent over the decade interval (Figure 3-16). The sampling year 2012 displayed an apparent slight drop in Total Richness, which matched the drop in Herb Richness (Figure 3-16)

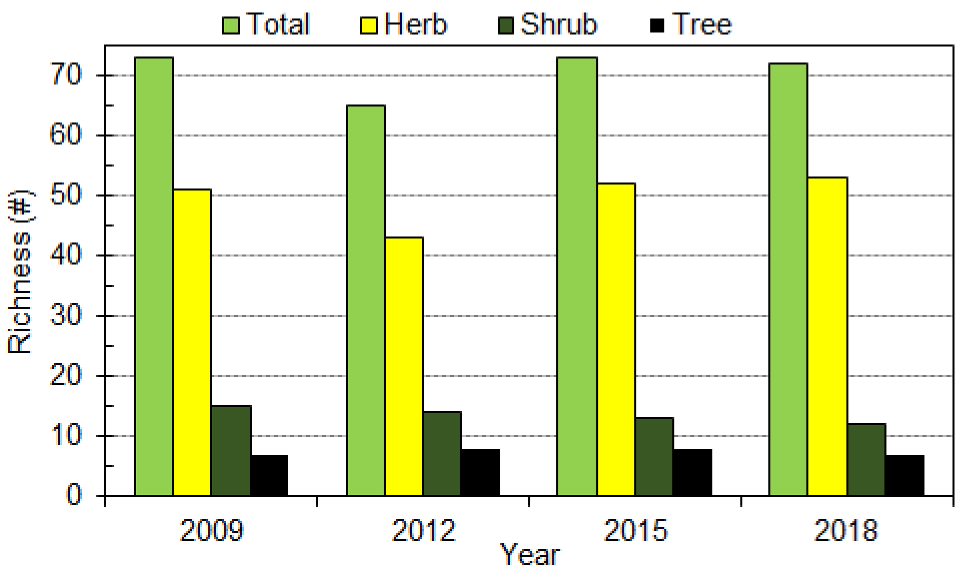


Figure 3-16: Total Richness (number of species) for all of the sites at the reservoir across years, grouped into three classes (Herb, Shrub, and Tree).

3.3.4 Environmental Factors

With the observed changes in vegetation Cover (abundance) over the decade interval, the next considerations investigated correspondences with the different environmental factors.

3.3.5 Site

Site provided the first environmental factor and represented the position along the reservoir. The Sites were primarily at depositional deltas at the outflows of tributary creeks and had been selected prior to the study as potentially providing opportunities for increased colonization by riparian vegetation.

Vegetation Cover

In 2018, as in prior years, there was substantial variation in the vegetation Cover across the Sites (Figure 3-17). The proportional rankings across the Sites were quite consistent, with higher values at all Sites in 2009. There was a major decrease in Cover in 2012 and subsequently at most Sites, the Cover in 2015 and 2018 was very similar. The exceptions were Sites 5, 10 and 12, which had lower Cover values in 2018.

Across the years, there was a decrease in vegetation cover after 2009 (Figure 3-17). From 2012 to 2018 there was a gradual decline overall by 2018. Variation between years for individual sites occurred across the sampling years of 2012 to 2018. Sites 5, 10 and 12 had decreasing cover across the years from 2009 to 2018 with 2009 having the highest vegetation for all sites.

With a shallower slope, Site 13 does not have the full, 10 m range in elevation that was included for the other Sites. Therefore, it has a high representation of the first three elevation brackets where most vegetation occurs. The first three metres of elevation change from full pool was compared for all the Sites along the reservoir. This comparison resulted in a significant difference between Site 13 and the other sites 11 Sites (P < 0.001 for all sites with a variation in Z-Statistic from -3.06 to -11.52). Therefore, when all sites only have the first 3 m change in elevation compared to Site 13; Site 13 still has a significant increase in vegetation cover suggesting that additional factors are responsible for the difference between Site 13 to all of the other sites.

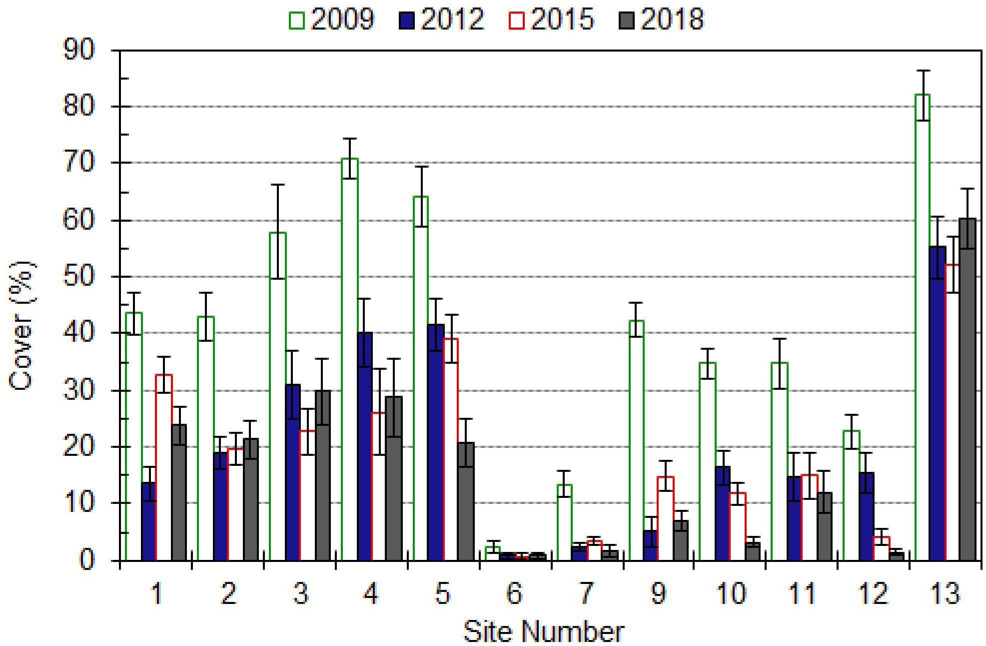


Figure 3-17: Total mean (± s.e.) vegetation cover for each Site for 2009 to 2018.

Dominant Species

There was reasonable consistency in the dominant plant species observed in the Duncan Reservoir draw-down zones from 2009 through to 2018 (Table 3-13). Common horse tail (*Equisetum arvense)* was the predominant species in 2018, as it has been since 2009. Sedge was the grouping of all sedge species and in 2009 only beaked sedge was identified, since most of the sedges lacked seed heads that are required for identification. In 2012 and 2015, we were able to identify two species, with beaked sedge the dominant species and different secondary species in each year. In 2018, the three species were confirmed with seed heads being common (Appendix 1). Due to the different assessments, all sedges were combined for the interannual comparison.

Table 3-13: The dominant plant taxa cover rank for 2009, 2012, 2015, and 2018. Perennials (P) and annuals (A) are indicated.

Common Name	Species Code	2009	2012	2015	2018
Common Horsetail (P)	*Equi_arv*	1	1	1	1
Sedge species (P)	*Care_spp*	2	5	4	2
Moss (A/P) depends on spp.	*Moss_spp*				3
Narrow-leaved Collomia (A)	*Coll_lin*				4
Green Smartweed (A)	*Poly_lap*	5	3	2	5
Nodding Wood-reed (P)	*Cinn_lat*	4	2	3	
Silvery Hair grass (A)	*Aira_car*	3		5	
Mouse-eared Chickweed (A)	*Cera_vul*		4		
Wormseed Mustard (A)	*Erys_che*		6		

The five dominant plant taxa for 2018 displayed substantial variation in Cover across the Sites (Figure 3-18). Common horsetail occurred at all sites except Site 7 and was the most abundant plant at four Sites. The second dominant grouping; mosses, occurred mainly at Sites 3 and 4 and were present at seven of the twelve sites. Sedges (Care.spp) occurred mainly at Sites 1, 9, and 13 with trace amounts at Sites 2 and 10. Narrow-leaved collomia (Coll.lin) occurred at the downstream end of the reservoir (Sites 1, 2, 3, and 4) with trace amounts at Site10. The fifth dominant species green smartweed (Poly.lap) occurred mainly at Site 1 and other Sites had some smartweed except Sites 7, 11, and 13.

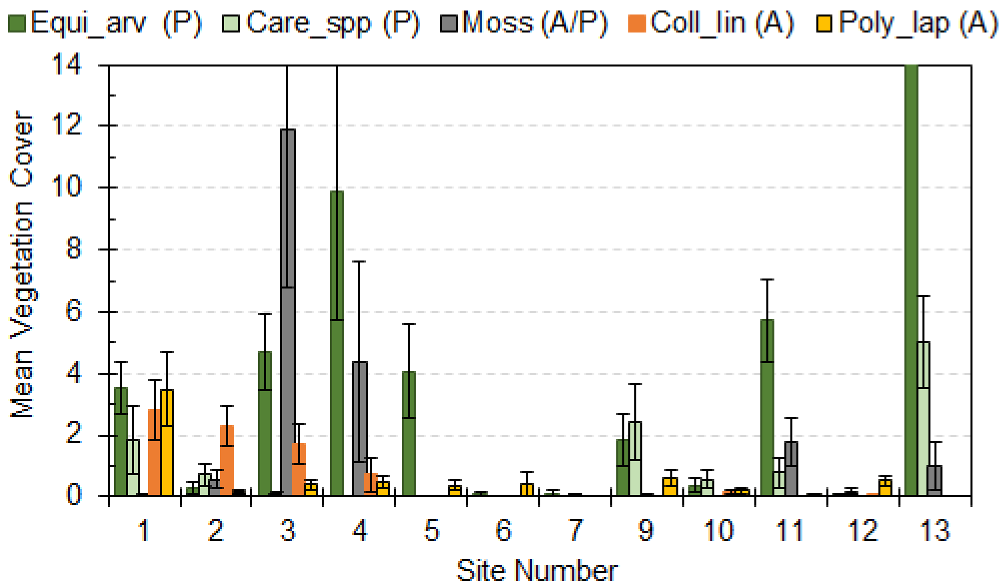


Figure 3-18: Mean (+ s.e.) per cent Cover for the five dominant plant species versus Sites in 2018 (A: annual; P: perennial). For Site 13, Equiv_arv was 43.8 per cent (s.e. 4.6) of the cover.

Species Richness varied about five-fold across the Sites and was highest at the southern sites, closest to the Duncan Dam (low Site numbers; Figure 3-19). The Richness in 2018 was slightly higher at Sites 1 and 2 and then very similar to the Richness values for previous years at the other Sites. Richness was generally lowest for the Sites with sparse vegetation, including Sites 6, 7 and 12. Conversely, Site 10 had sparse Cover but considerable Richness, while Site 11 displayed an opposing pattern, with considerable cover but lower Richness.

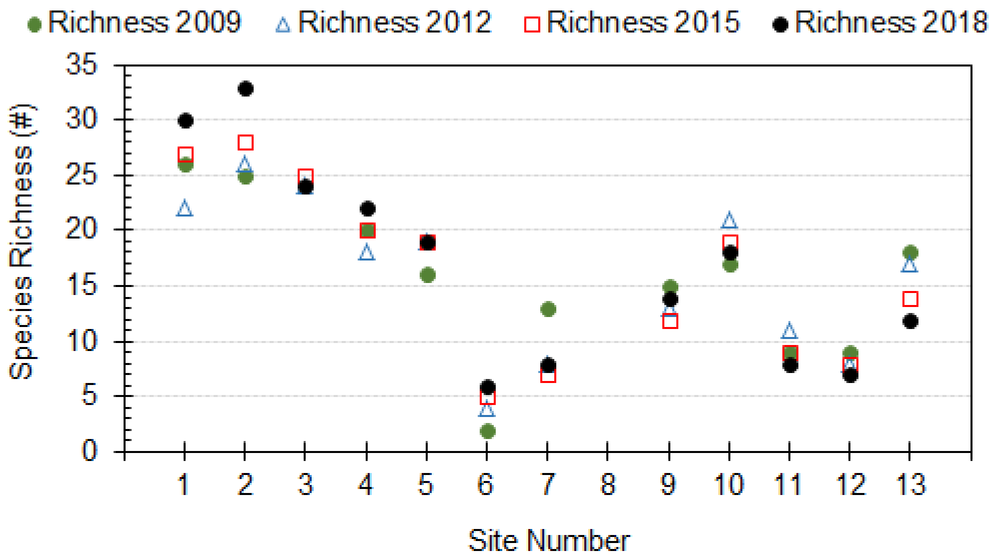


Figure 3-19: Plant species Richness versus Site along the Duncan Reservoir drawdown zone in 2009, 2012, 2015, and 2018.

Species Diversity

Species diversity varied across Sites within the southern end of the reservoir (Sites 1 to 5) generally having higher diversity (Figure 3-20). Site 6 had very sparse vegetation by two species resulting in a very low 2009 value. In subsequent years, Site 6 cover remained low but with increased species richness which increased diversity. However, compared to the other Sites diversity remained low. The middle to northern sites had an increase in diversity to Site 10. Sites 11, 12 and 13 were along the west bank of the reservoir suggesting lower diversity along that shoreline.

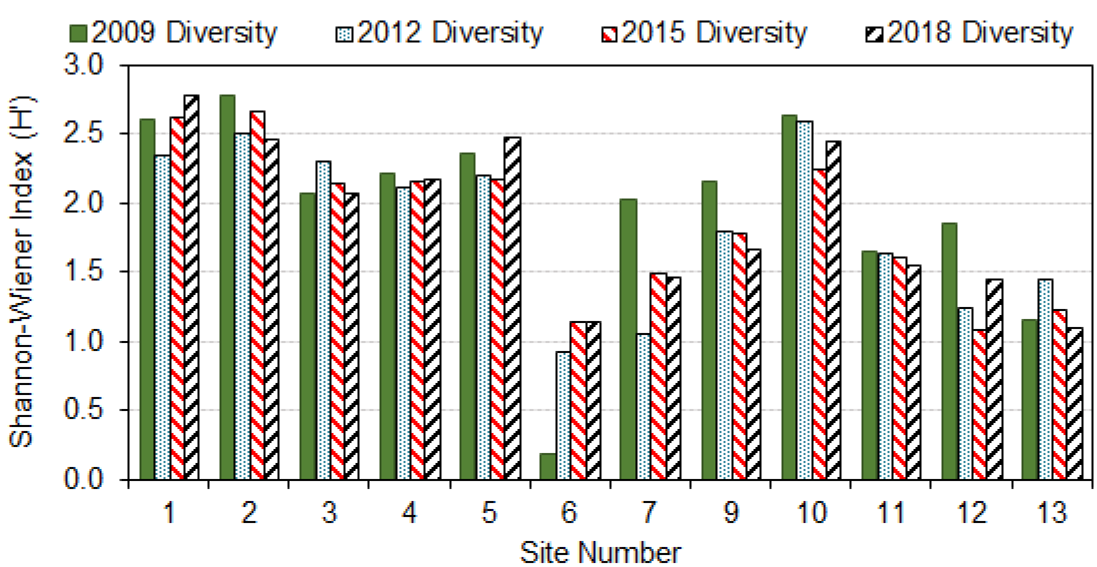


Figure 3-20: Shannon-Wiener indices of diversity (*H'*) by sites for 2009 to 2018.

3.3.6 Elevation

Vegetation Cover

Increased vegetation Cover was noted with progress up the transect elevations to 576.7 m. Per cent cover was similar from 2012 to 2018 at the -1 m bracket (576.7 m to 575.7 m (-1)) compared to 2009. The 2018 cover had a gradual decrease in cover with decreases in elevation compared to 2012 and 2015 (Figure 3-21). All sampling years show a decrease in cover from full pool down to -10 m into the drawdown zone from 2009.

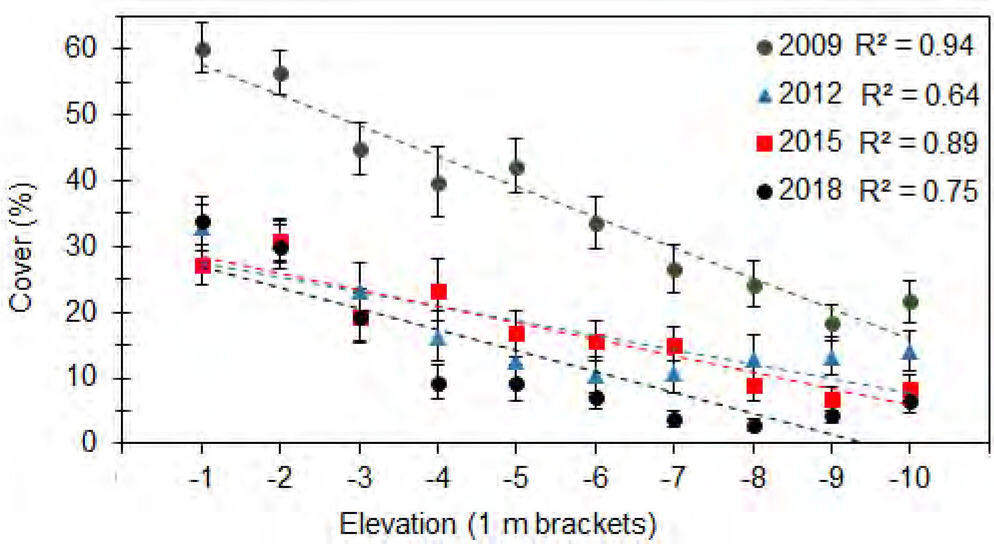


Figure 3-21: Mean (±s.e.) vegetation per cent (cumulative) versus elevation for quadrat data grouped in 1 m elevational intervals for 2009 to 2018.

The 85th percentile was 576.04 m, with 0.64 m change in elevation from full pool being exposed for 85 to 100 per cent of the growing season in 2018. Therefore, the first -1 m change in elevation is greater than the 85th percentile range that is exposed. This elevation band is where the majority of the shrub and tree species occurred. There were some woody species occurring with the low cover in the -2 m elevation band at the herb and shrub size quadrats, but no trees (> 2.0 m tall) (Figure 3-22). When woody species occurred in the -2 m band, they generally occurred at the upper end of the metre band in elevation. Woody species that were less than or equal to 0.5 m tall were assessed in the herb quadrats but separated out for this analysis, in order to investigate the level of inundation that limits woody species recruitment and survival. No woody species were recorded in the -3 m bracket or lower in the drawdown zone. Both grass and herbaceous species had slightly lower vegetation cover at the -1 m elevation drop as compared to the -2 m band.

Similar trends occurred in previous sampling years with decreases in herbaceous cover at the -1 m and -2 m band. The shrub layer stayed consistent for sampling years 2009 and 2012 with shrub cover decreasing in 2015 and recovering in 2018 at the -1 m band (Figure 3-22). This contrasts with the -2 m elevation which shows a slow but steady increase in shrub cover for the elevation bracket. The drop in shrub cover at the -1 m bracket in 2015 may be a result from the July above full pool levels in 2012.

The tree cover is higher at the -1 m bracket with a steady increase since 2009. The tree cover that occurred within this bracket had trees occurring within the 0.5 m drop in elevation (576.7 m to 576.2 m) which is within the 85th percentile of the reservoir elevation for the previous years. At the -2 m bracket there was a slight increase from zero in 2018 but tree cover did not account for measurable cover during the study period.

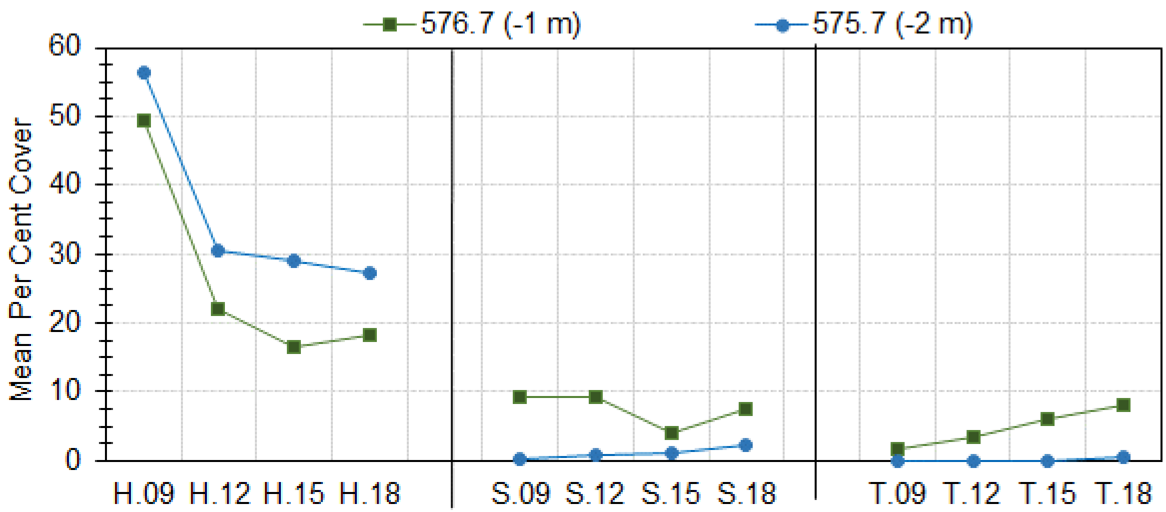


Figure 3-22: Mean per cent cover for Herb (H), Shrub (S), and Tree (T) quadrats for the four sampling years within the -2 m change in elevation brackets from full pool.

Dominant Species by Elevation

For the five dominant species, it appears that perennials decrease as elevation decreases from full pool while the two annual species have a reverse gradient with cover decreasing as elevation increases toward full pool. Figure 3-23 shows these species listed in their ranked order from highest to lowest versus the elevation gradient. Common horsetail and sedges were the perennial species that occurred at high densities at the -2 m change in elevation bracket. Sedges did not occur below -5 m while common horsetail occurred through all elevations but at a reduced cover past the -4 m elevation bracket. At the lower elevations, common horsetail vegetation was composed of first year seedlings. The sedges were remnants of sedge communities that were probably large areas and well established before Alt 73 regime started. Cover has been decreasing at the -4 m and -5 m elevation since 2009 for sedge species.

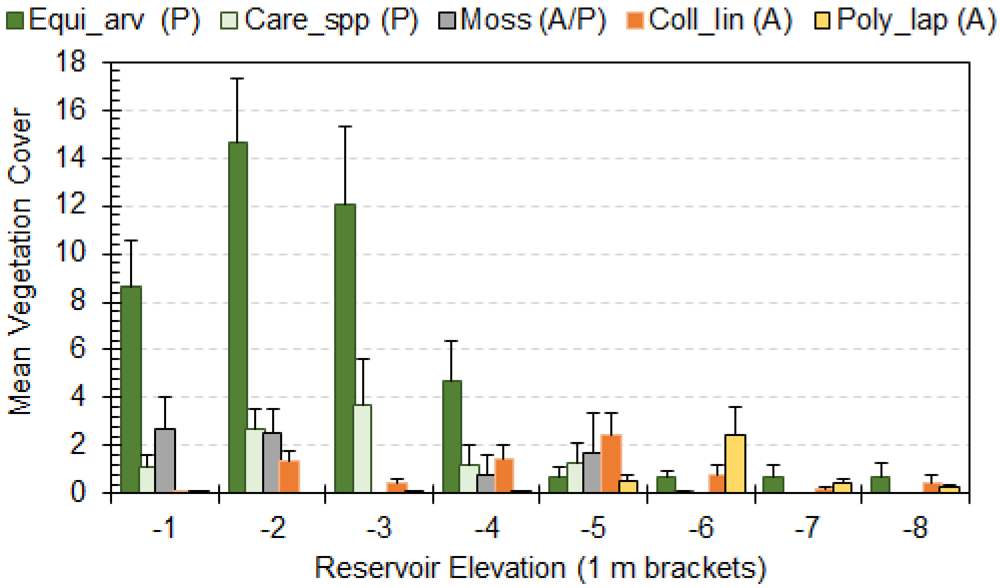


Figure 3-23: Mean (+ s.e.) per cent cover for the five dominant plant species versus elevation brackets within the drawdown zone of Duncan Reservoir in 2018.

When all of the annual species are plotted next to the perennials, a clear trend emerges similar to the findings in 2012 and 2015. Annual species dominated the lower elevations of the drawdown zone and perennials were predominant in the upper elevations (Figure 3-24). Elevation bracket -2 m has the highest herbaceous cover in 2012, 2015, and 2018. Elevation bracket -1 m is impacted by woody debris reducing herbaceous cover. The perennial species that occurred within and below the elevation bracket -6 m was dominated by common horsetail.

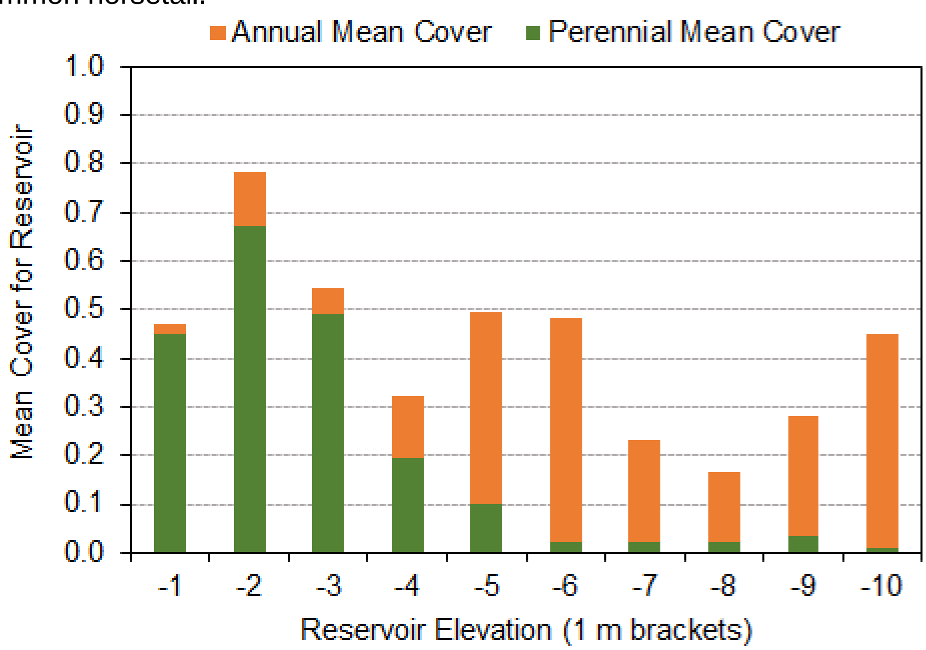


Figure 3-24: The mean per cent cover for annual and perennial plants versus the elevation brackets at which they occurred within the Duncan Reservoir drawdown zone in 2018.

Species Richness

There were 72 species recorded within the reservoir drawdown zone for the 12 sites sampled. These species were split into three categories:

- 53 herbs made up of forbs, graminoids, mosses, and ferns and grouped as 'Herb';
- 12 species of shrubs; and
- 7 species of trees.

Not all shrub species were recorded within shrub plots, small shrub species <0.5 m tall were always recorded with herb plots because of their size. Other exceptions were seedlings of tree and shrub species recorded in herb plots and or within tree or shrub plots because of their size and not what species they were. The complete list of species (common and scientific names) as well as codes (first 4 letters of genus and first 3 letters of species) is located in Appendix 1.

Species richness also followed an elevation gradient from high (62 species) within the first metre of full pool elevation (576.7 m) to low (11 species for brackets -8 m) (Figure 3-25). The top metre bracket (-1 m) is the band where the majority of the tree and shrub species occurred. Comparison across sampling years, 2009 to 2018 showed a similar pattern for all years.

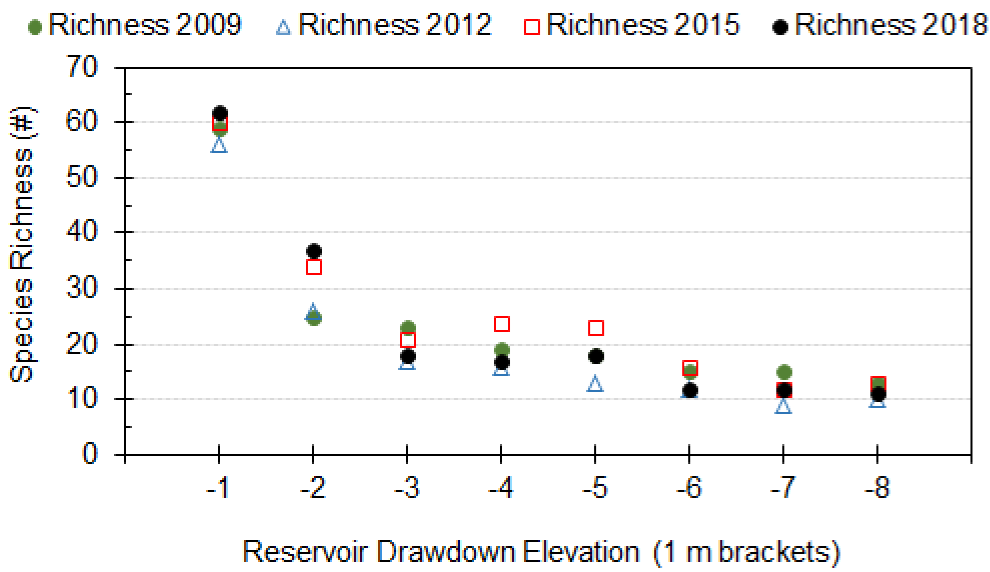


Figure 3-25: Plant species richness versus elevation in the Duncan Reservoir drawdown zone in 2009, 2012, 2015 and 2018. Reservoir elevations are in one-meter increments, starting at full pool (0 to -1 m bracket) and dropping to -8 m (-7 m to -8 m) below full pool.

Species Diversity

The Shannon-Wiener (*'H'*) or "Shannon" index varied across the elevations, with the lowest on average for bracket -3 m in the drawdown zone for years 2012 to 2018 (Figure 3-26). The highest *'H'* values were observed for elevation bracket -1 m. The lowest *'H'* value occurred in 2018 (1.3) for the elevation bracket -3 m.

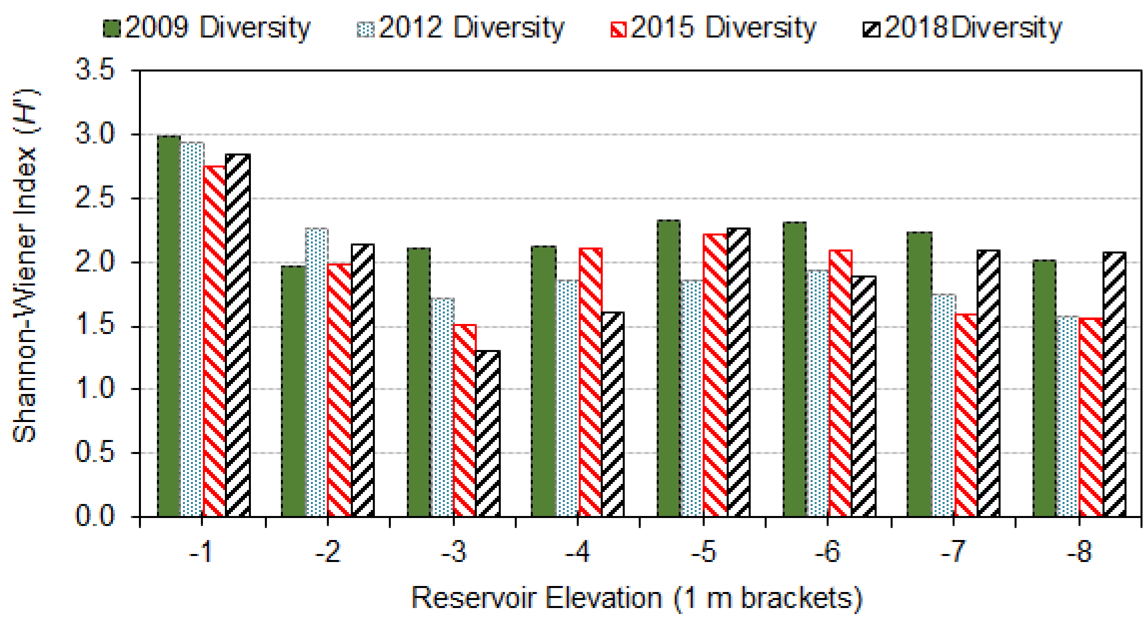


Figure 3-26: Vegetation diversity (Shannon-Wiener diversity (*'H'*)) versus 1 m elevation brackets for 2009 to 2018.

3.3.7 Exposure

The reservoir duration of exposure related to the reservoir drawdown zone elevations was investigated in 2018. Exposure time was graphed versus elevation (in 1 m brackets) to evaluate the differences between these two correlated factors. Figure 3-27 shows the non-linear association between the factors.

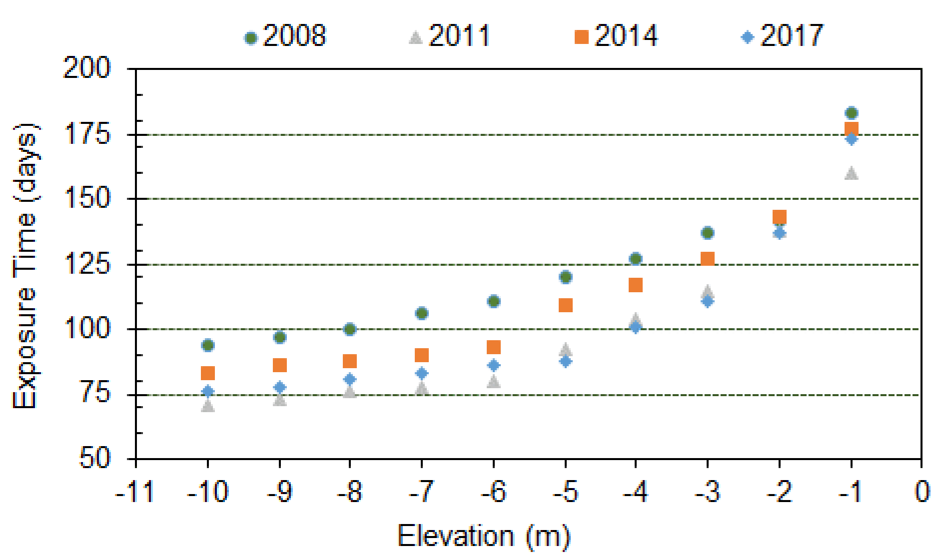


Figure 3-27: Exposure time versus elevations across the study years.

The new factor, Exposure was graphed for mean vegetation cover by exposure time (Figure 3-28). The trendline slopes are consistent with cover increasing with increasing exposure. There is a clear and consistent downward shift from 2009 to the other three sampling years, which are similar. Exposure should have partly absorbed the Year influence, but it did not. This indicates that not only the stage pattern, but an additional factor(s), is contributing to the decline of vegetation cover after 2009.

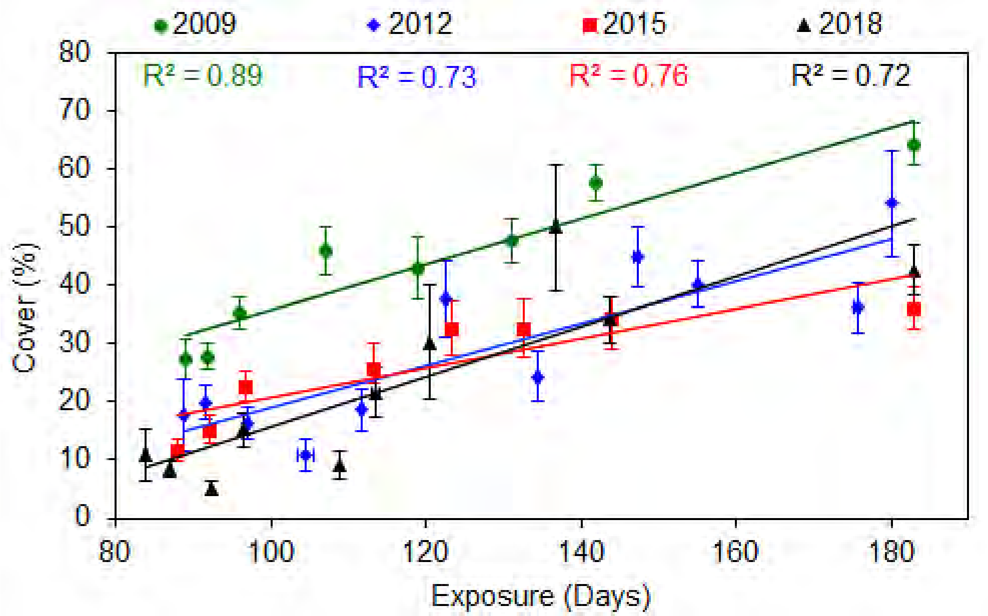


Figure 3-28: Mean (±s.e.) vegetation per cent (cumulative) for the reservoir for each year versus the exposure days that occurred for the year preceding the June sampling date of the vegetation. The x axis s.e. are smaller than the symbols.

Exposure times were compared from 2008 to 2017 with the exposure times in days for each elevation bracket for the growing season each year (Table 3-14).

Table 3-14: Exposure time (days) that occurred during years from 2008 to 2017 (the year influencing the June 2018 vegetation inventory). The colour coding indicates the degree of impact from inundation (green – favorable (>160 days), yellow – intermediate (> 105 days, red – unfavorable (<105 days) (Hawkes and Gibeau 2015)). The categories are defined in 2.3.4 Environmental Factors – F. Exposure Time.

	Year									
Elevation	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
575.7 (-1m)	183	140	170	160	171	171	177	180	183	173
574.7 (-2m)	142	135	153	138	133	129	143	180	151	137
573.7 (-3m)	137	109	133	115	120	105	127	172	137	111
572.7 (-4m)	127	90	120	104	112	82	117	150	126	101
571.7 (-5m)	120	78	101	92	104	81	109	129	114	88
570.7 (-6m)	111	75	97	80	95	79	93	109	103	86
569.7 (-7m)	106	71	92	78	88	77	90	95	98	83
568.7 (-8m)	100	66	89	76	86	75	88	91	94	81
567.7 (-9m)	97	62	86	73	85	73	86	88	91	78
566.7 (-10m)	94	59	82	71	83	71	83	85	88	76

Table 3-15 shows all years of the study period for each month of the growing season. The percentage of time of Inundation is shown as a requirement of BC Hydro (2017) but for analysis of the study years this was converted to Exposure time in days. The colour coding is explained in Section 2.3.4 Environmental Factors with the short form of: green = favorable (> 160 days), yellow = intermediate (>105 days), and red = unfavorable (<105 days).

Table 3-15: Monthly inundation percentage (1 = all days for the month exposed), for the Alt S73 time period.

		Reservoir Elevation									
		566.7	567.7	568.7	569.7	570.7	571.7	572.7	573.7	574.7	575.7
Apr	2008	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2012	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2014	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2016	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2017	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
May	2008	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2012	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2014	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2015	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2016	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2017	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jun	2008	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2009	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2010	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2011	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2012	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2013	0.90	0.94	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00
	2014	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2015	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2016	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	2017	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jul	2008	0.11	0.16	0.21	0.30	0.38	0.51	0.61	0.74	0.81	1.00
	2009	0.67	0.76	0.84	0.92	0.96	0.99	1.00	1.00	1.00	1.00
	2010	0.43	0.52	0.60	0.70	0.80	0.90	0.97	1.00	1.00	1.00
	2011	0.19	0.25	0.30	0.37	0.43	0.52	0.58	0.71	0.81	1.00
	2012	0.12	0.17	0.21	0.26	0.31	0.36	0.40	0.45	0.48	0.84
	2013	0.00	0.01	0.03	0.05	0.07	0.16	0.25	0.48	0.65	1.00
	2014	0.15	0.20	0.26	0.32	0.38	0.47	0.54	0.68	0.77	1.00
	2015	0.19	0.27	0.35	0.47	0.57	0.75	0.90	1.00	1.00	1.00
	2016	0.00	0.00	0.10	0.23	0.39	0.52	0.68	0.84	1.00	1.00
	2017	0.07	0.11	0.15	0.21	0.26	0.34	0.41	0.55	0.65	1.00
Aug	2008	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	2009	0.00	0.00	0.00	0.03	0.06	0.16	0.26	0.58	0.84	1.00
	2010	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.24	0.45	1.00
	2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.39	0.90
	2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.13	1.00
	2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.13	1.00
	2015	0.00	0.00	0.00	0.08	0.16	0.38	0.60	0.87	1.00	1.00
	2016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	2017	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.19	1.00
Sep	2008	0.00	0.04	0.08	0.18	0.28	0.44	0.57	0.75	0.87	1.00
	2009	0.00	0.00	0.00	0.06	0.12	0.32	0.52	0.83	1.00	1.00
	2010	0.00	0.00	0.00	0.12	0.23	0.45	0.67	0.88	1.00	1.00
	2011	0.00	0.06	0.12	0.25	0.37	0.59	0.74	0.92	1.00	1.00
	2012	0.04	0.11	0.18	0.30	0.42	0.58	0.70	0.88	1.00	1.00
	2013	0.00	0.00	0.00	0.00	0.00	0.18	0.36	0.77	1.00	1.00
	2014	0.00	0.09	0.17	0.30	0.43	0.63	0.73	0.90	1.00	1.00
	2015	0.11	0.27	0.44	0.63	0.83	0.97	1.00	1.00	1.00	1.00
	2016	0.00	0.00	0.00	0.00	0.00	0.23	0.47	0.67	0.97	1.00
	2017	0.00	0.00	0.00	0.08	0.17	0.32	0.47	0.77	1.00	1.00

3.3.8 Substrate

The Substrate texture index (1 = silt, very fine to 5 = bolder, very coarse) showed a steady increase of particle size with decreasing elevation similar to previous surveys (Figure 3-29). There has been an increase in substrate texture from -3 m bracket to -8 m bracket in 2018 compared to previous years. The finer substrate is being eroded away with reservoir level fluctuations especially from the -3 m elevation bracket to -8 m gradient.

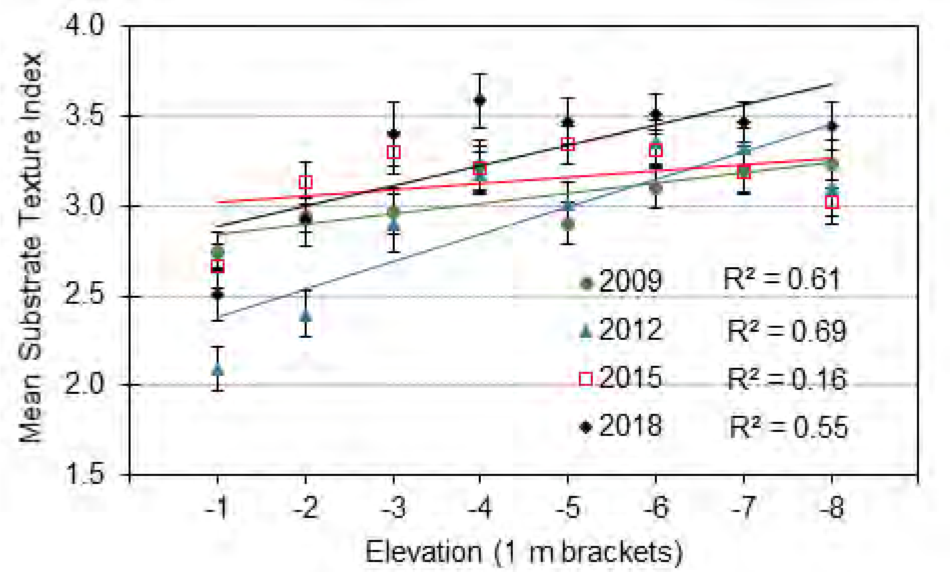


Figure 3-29: Mean (± s.e.) substrate texture index versus elevation grouped into 1 m elevational intervals for 2009, 12, 15, and 18. Substrate texture index (1 = silt (very fine) to 5 = bolder (very coarse)).

The substrate texture index showed variation for sites across the years (Figure 3-30). Site 1 remained similar across years with Sites 3 and 4 showing the most variation across years. The middle to the upstream end sites has higher substrate textures (courser) compared to the downstream sites. Consistent with previous comparisons by site, Site 13 is the exception with it being the most upstream site but with the finest texture index.

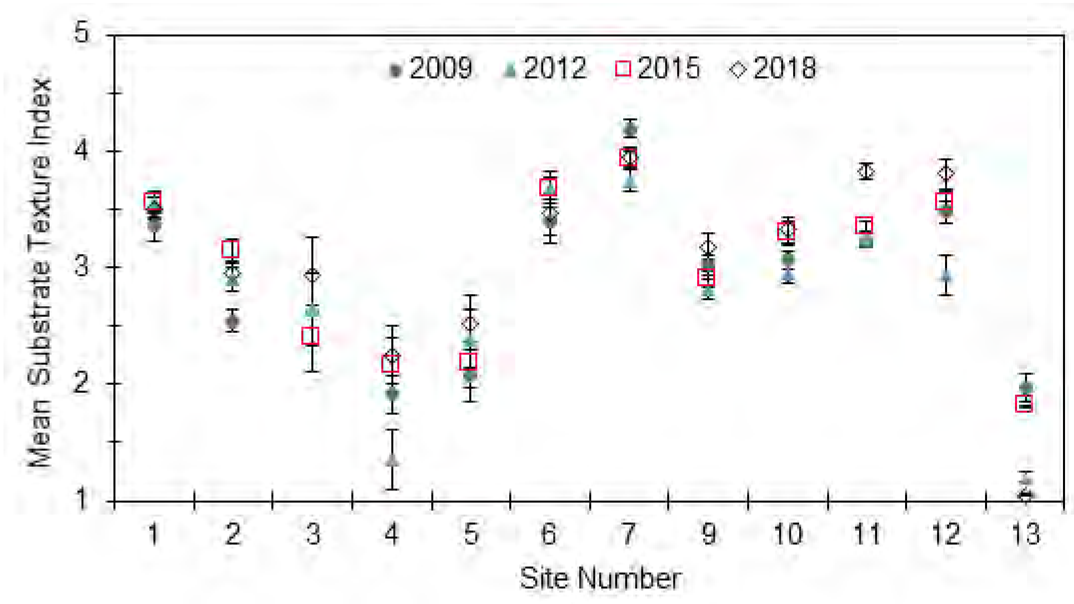


Figure 3-30: **Mean (± s.e.) substrate texture index for each site for 2009, 2012, 2015, and 2018.**

The vegetation cover by the substrate texture index was graphed across the quadrats for the four sampling years (Figure 3-31). As substrate increased in coarseness, vegetation cover decreased, i.e., finer substrates (lower values) are favoured by vegetation. There's a downward pattern, apparently similar across years, although 2015 has some low values around 1 that distort the pattern. The 2012 and 2018 regressions are very similar.

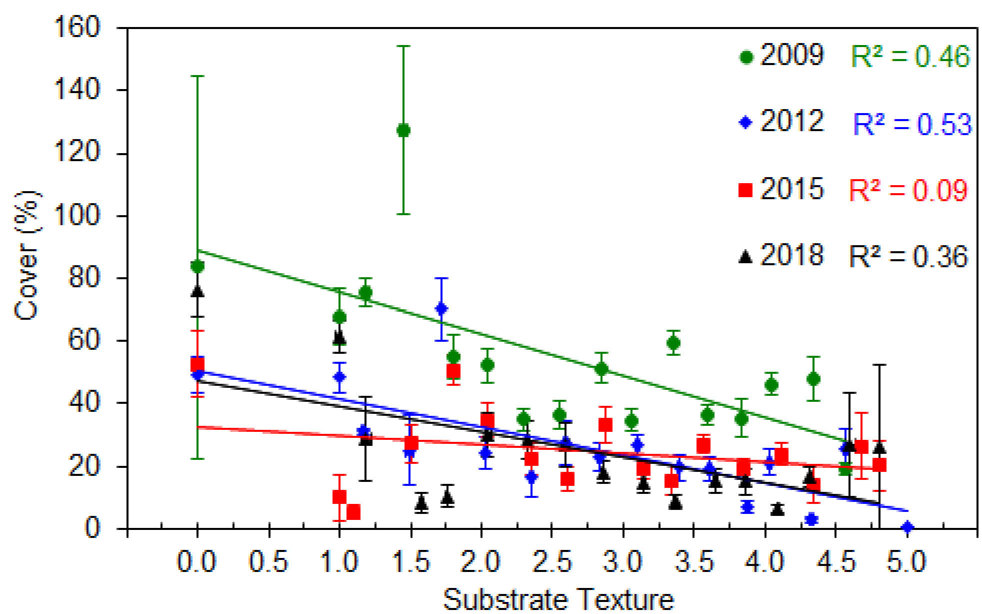


Figure 3-31: **Mean (± s.e.) vegetation cover versus the substrate texture index for all sites in the drawdown zone of Duncan reservoir for 2009 to 2018.**

Dominant Species

The five dominant species for 2018 were then graphed versus the substrate texture index. The scatter plot was difficult to see the differences between species; and consequently, the substrate texture index was grouped into 0.5 brackets with the average for each species graphed within each bracket (Figure 3-32). There were no mid-points for index categories 4.6 to 4.8 for the five dominant species.

Common horsetail highest cover occurs on the finest texture which is the main texture for Site 13. Moss is found mainly where fine substrate texture occurs. Sedges appear to have the highest cover within the texture bracket 2 which is a fine substrate. Smartweed grows well on the 2.5 to 3 substrate texture index and vegetation cover is low for the course texture index ratings for all of the five dominant species with no common horsetail occurring at the 4.7 and 4.8 course texture index category.

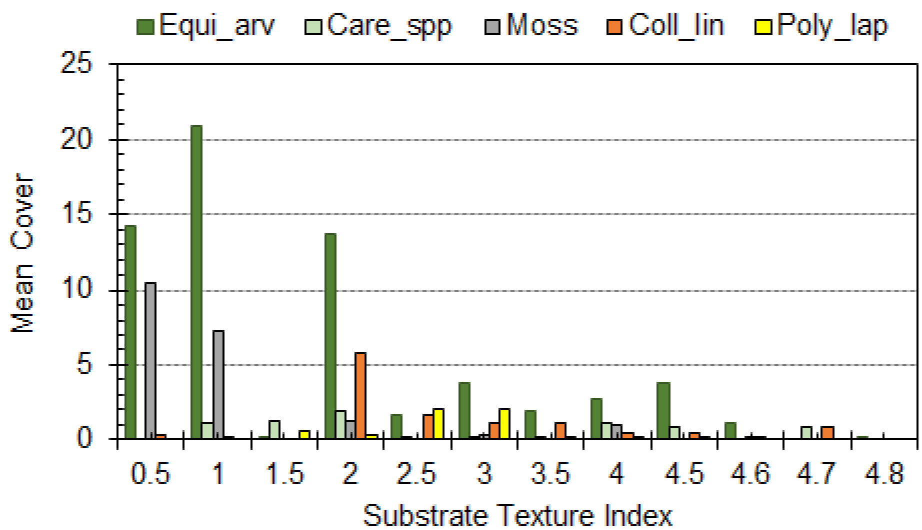


Figure 3-32: Average cover for the five dominant species in 2018 versus substrate texture index.

Common horsetail and moss had the strongest association with substrate texture with R^2 = 0.49 and R^2 = 0.46 respectively. Sedge did not show a strong association with substrate texture (R^2 = 0.07) nor was there an association for narrow-leaved collomia or green smartweed (R^2 = 0.05 and R^2 = 0.04 respectively).

3.3.9 Slope

Steep slopes show a gradient of reduced vegetation cover from shallow slopes to steep slopes. The regression plots display a downward shift after 2009 and then consistent patterns for the other years. Slope was a significant influence, but it was also partially correlated with Substrate (steep slopes don't have fine sediments).

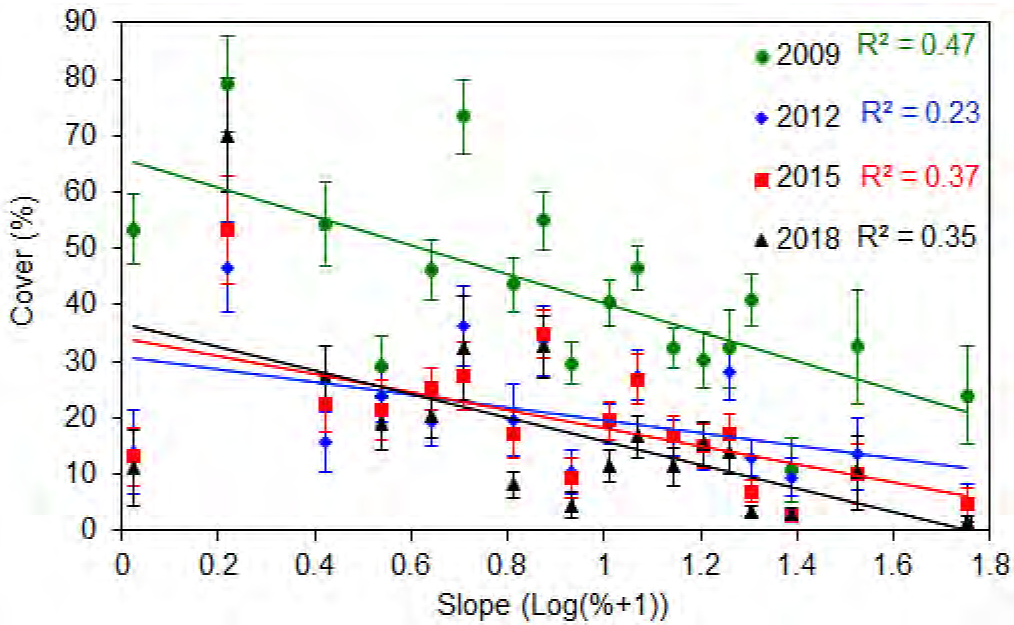


Figure 3-33: Mean (± s.e.) vegetation cover versus slope for all Sites in the drawdown zone of the Duncan reservoir for 2009 to 2018.

3.3.10 Bare Ground

By Site

Bare ground averaged for each site illustrates the differences across sites (Figure 3-34). The 'Water' category included flowing and pooled water that occurred along transect lines during sampling (water occurred at other sites but not along transects) and was recorded for four of the twelve sites. There is an increase in the total bare ground from the middle to the upstream end of the reservoir with Site 13 the exception. Additionally, Site 13 does not have 'Rock' and has the smallest amount of total bare ground. Note that 'Soil' means any bare ground that is not boulders, bedrock, wood, or water.

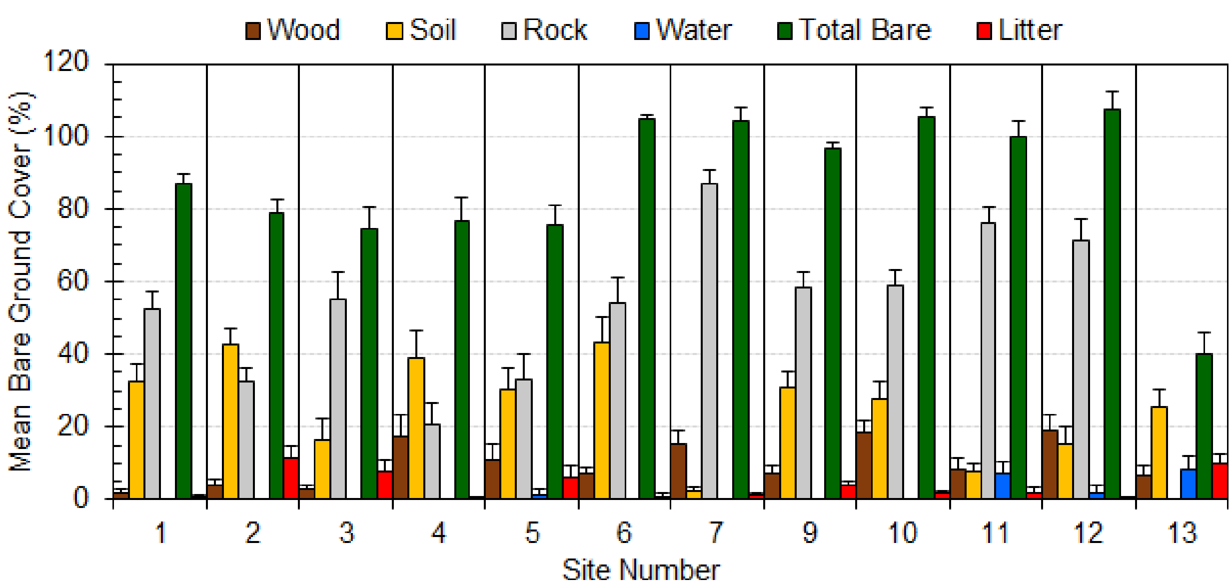


Figure 3-34: Mean (+ s.e.) bare ground and litter covers by sites for 2018.

By Elevation

Bare ground was graphed by elevation. Woody debris (Wood) had a moderate association with elevation change (R^2 = 0.64). Woody debris mainly occurred at the -1 m bracket below full pool. Bare ground, broken into 'Soil' and 'Rock', where Soil was all bare ground that was not rock had the same increase with decreasing elevation into the drawdown zone as in 2015 (Figure 3-35). Rock had a steady increase as the elevation dropped with a strong association (R^2 = 0.77). Bare ground listed as 'Soil' had an R^2 = 0.47 with a dramatic increase at the -3 m elevation bracket and then levels off for the lower elevations (-3 m to -8 m). When all bare ground is combined, the R^2 = 0.82 indicating a strong association with increasing bare ground as the elevation decreases. Litter was highest at the 1 m bracket with low levels at the -2 and -3 metre brackets and close to zero or zero at the lower elevations. This indicates that the plant growth in the late summer and early autumn growing season produces very small amounts to no dead plant material. As the following spring, when sampling occurs, there has been no inundation to remove the buildup of litter. At the -1 m bracket, the top end of the bracket in most years does not get inundated so litter is available to buildup on the ground surface.

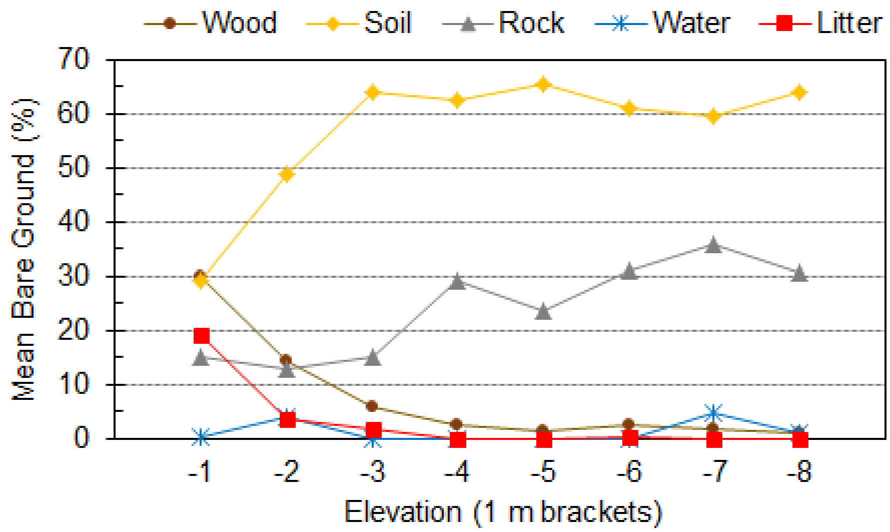


Figure 3-35: Mean bare ground and litter covers by elevation for all sites combined.

3.3.11 Spatial Distribution Pattern by Site

As another means of simultaneously considering vegetation cover and species richness, the mean values for these two measures were plotted for each site in previous reports. This graphical approach is similar to ordination, although only two measures are included. Along with the plotting, we have identified apparent clusters of sites with similar vegetation characteristics.

In 2009, there were distinct groups of sites at the downstream (dam) end of the reservoir, the peninsula (Sites 4 and 5) grouped with the downstream end, and the upstream end of the reservoir. Site 6 was unique and occurred in the middle reach and Site 13 occurred in the Delta area of the reservoir (Figure 3-36). This tight grouping by geographical location changed across years with less defined groups by location by 2018.

In 2012, there was no longer a peninsula group as Sites 4 and 5 were grouped with the downstream end. Site 2 moved out of the downstream group and Sites 6 and 7 were grouped representing the middle of the reservoir gradient (Figure 3-36). Site 13 remains unique in the Delta section of the reservoir in 2012. See Figure 2-1 for physical locations.

In 2015, there were new shifts in groups with Site 2 moving back into the downstream end, and the upstream end consisted of Sites 9, 10, and 11. There was a new group, Sites 7 and 12 that were very similar. However, Site 12 is located at the most upstream end of the reservoir and Site 7 occurs in the middle (Figure 3-36).

In 2018, there is further loss of distinct grouping by geographical location. Site 2 moved out of the downstream end group again. The downstream end cluster is similar to the 2012 cluster but not as tightly grouped. The upstream end group is similar to the 2015 cluster. Site 6 remains in the Middle position but Sites 7 and 12 are now similar to Site 6 but with higher richness (Figure 3-36).

In 2012, data shows a decrease in richness for all sites compared to 2009. The cover showed variation with some sites increasing cover while other sites had decreased cover in 2012 compared to 2009.

Shifts in site positions in 2015 compared to 2012 had the downstream end group with similar cover and an increase in richness. The upstream end had similar cover and richness but not clustered as tightly as in 2012. Site 12 that moved out of the upstream end group had a decrease in cover and richness. Site 6 remained consistent compared to 2009 and 2012. The delta Site 13 had a similar cover but an increase in richness.

By 2018, the pattern of reservoir position related to vegetation cover and vegetation richness is not as evident as in 2009. There still are downstream end and upstream end groups. However, there are sites within the two groups that are no longer associated closely with the groups. Similar to previous sampling years, decreases in cover and or in richness were responsible for the sites shifting in and out of groups. The two sites that were the exception, Sites 6 and 13 remained in similar position for each of the sampling years.

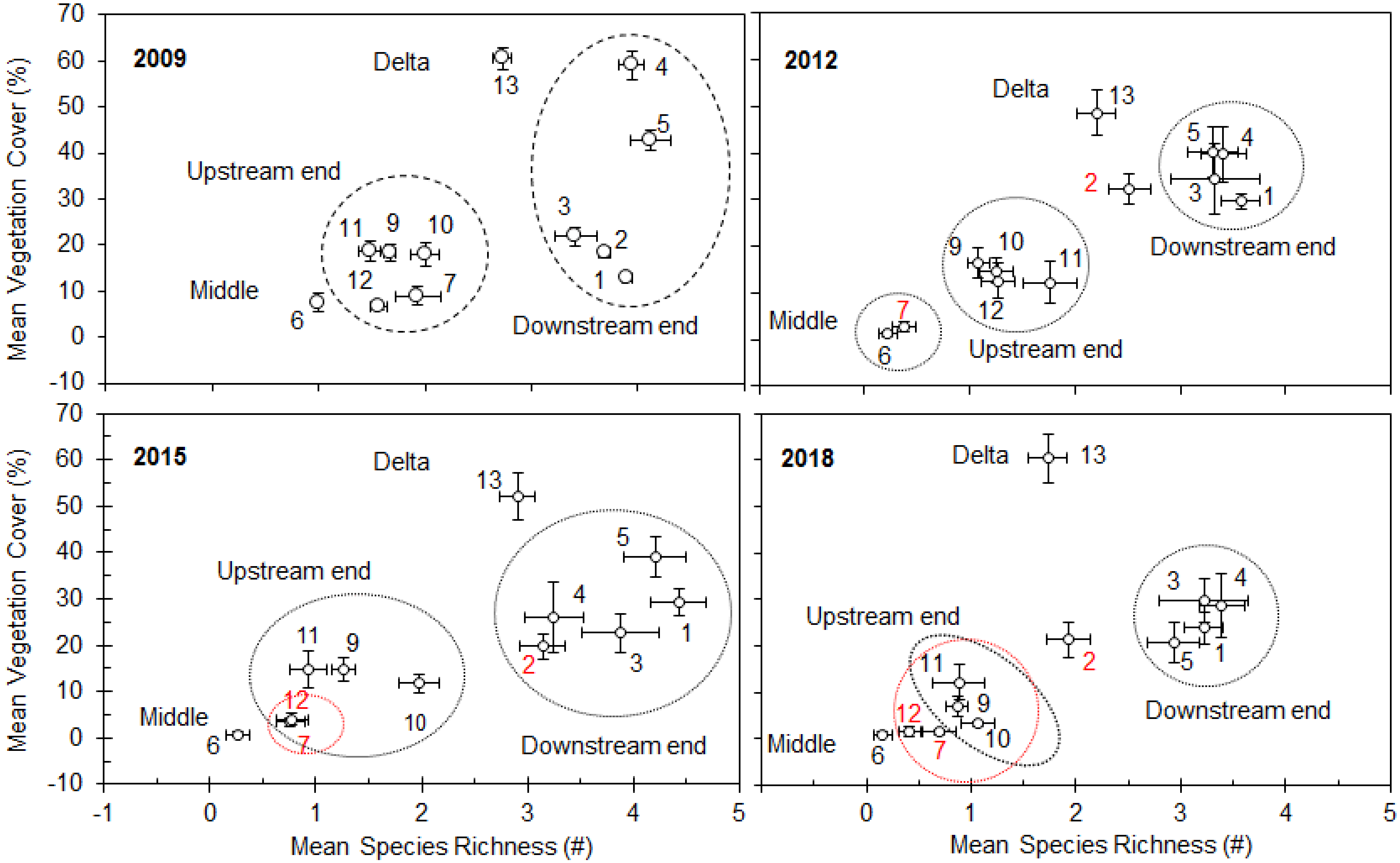


Figure 3-36: **2009, 2012, 2015, and 2018 mean (± s.e.) vegetation cover (cumulative per cent cover) versus mean (± s.e.) species richness for quadrats at 12 sites (site # next to point) in the drawdown zone of Duncan Reservoir. Apparently similar sites are enclosed in the dashed circles and oval.**

3.4 Associations between Vegetation Characteristics and Environmental Factors

3.4.1 Bivariate Correlations

Some of the correlations between environmental factors and vegetation characteristics have already been presented in the preceding sections, with linear regressions for particular years. In preparation for the factor analysis, we undertook a further, systematic assessment of all pairings, with the combined results from all Years.

As indicated in the Methods, we undertook conventional Pearson product-moment correlations (*r*), as well as two non-parametric rank order tests, the Kendall τ-b and Spearman rho. The three tests produced very similar outcomes and we will primarily present the Pearson *r* results.

As described in the Methods, for consideration as a prospectively important association we required that a correlation must reach the statistical threshold of $p < 0.01$. This elevated standard reflected a large number of pairings and repeated analyses of the same quadrat positions, which violated the requirement for sample independence.

<u>Environmental Factors</u>

We analyzed the environmental factors as presented in Table 3-16. For this, we substituted Location nomenclature for Site, with slight renumbering to fill the gap for the deleted Site 8 and with sequencing from the Dam northward, including the three Sites along the west shoreline.

Table 3-16: Pearson product correlation coefficients (*r*) between paired environmental factors, for ~600 vegetation quadrats assessed at four triennial intervals, at twelve Sites along the Duncan Reservoir. Positive correlations of 0.2 or more are in red, while negative correlations, -0.2 or below, are in blue (= *p* < 0.01).**

	Location	Distance	Elevation	Exposure time	Substrate	Slope	Aspect
Year	.000	.000	.000	-.038	.056**	.000	.000
Location		-.352**	-.102**	.099**	-.089**	.090**	-.284**
Distance			.534**	-.488**	-.039	-.353**	.069**
Elevation				-.909**	.140**	.099**	.070**
Exposure time					-.213**	-.099**	-.114**
Substrate						.306**	.240**
Slope							.102**

Of the substantial correlations, Distance and Aspect were negatively correlated with Location (Table 3-16), partly reflecting the long and west-facing transects in the Sites closest to the Dam and particularly Sites 1 and 2 at Glacier Creek. Elevation represented the downward progression, and this increased with Distance. Elevation was of course strongly negatively correlated with Exposure time, with 81% correspondence (-0.909^2). With these correlations, the position characteristics of Elevation, Distance and Exposure are somewhat redundant, and analytical or predictive models would usually include only one of these three.

Exposure and Substrate were negatively correlated (Table 3-16) since finer sediments were common in some positions closer to the full pool shorelines. Substrate and Slope were correlated as fine sediments are readily washed from steeper slopes. While Substrate was correlated with Aspect, due to the common alignments at Sites, there was limited variation in this factor, which was correlated with Location.

Vegetation Characteristics

As indicated in the Methods, we considered Cover and Log conversions, which may normalize the distributions. For Richness, we considered square root conversion, which has been applied for some other vegetation community studies.

Most of the vegetation characteristics were positively correlated (Table 3-17). Relative to Cover, Total Cover was predominantly due to Herb Cover, and these were thus largely redundant. Slightly surprisingly, Herb Cover was not correlated with Shrub Cover, and this probably reflects the extensive zones below about 3 m below full pool, which supported herbaceous plants but rarely shrubs.

Table 3-17: Pearson product correlation coefficients (*r*) between paired vegetation characteristics, for ~600 vegetation quadrats assessed at four triennial intervals, at twelve Sites along the Duncan Reservoir. Positive correlations of 0.2 or more are in red, while pairings of values with their transformations are in purple and underlined (H = Herb; S = Shrub; Sqrt = square root) (= *p* < 0.01).**

	Log Cover	Herb Cover	Log HCover	Shrub Cover	Log SCover	Richness	Sqrt Rich.	Herb Rich.
Cover	.846**	.895**	.780**	.410**	.378**	.460**	.464**	.393**
LogCover		.804**	.957**	.252**	.274**	.592**	.653**	.557**
HerbCover			.849**	-.019	-.006	.401**	.420**	.419**
LogHCover				.035	.051	.559**	.623**	.581**
ShrubCover					.900**	.223**	.190**	.034
LogSCover						.246**	.219**	.045
Richness							.945**	.953**
SqrtRichness								.912**

The correlations between Cover and Richness may be most important and they were strongly correlated (Table 3-17), except for the combination of Shrub Cover and Herb Richness. The positive correlations suggest that environmental conditions that are favorable for vegetation Cover would also be generally favorable for species Richness, and thus multiple plant taxa would benefit. For this pairing, while the Pearson r was 0.653, Kendall's τ was also highly significant ($p < 0.01$) but slightly lower at 0.549.

For the pairings, the Log conversion of Cover consistently increased the correlations while the changes following the square root conversion of Richness were irregular (Table 3-17). These findings encourage analyses with the transformed Log Cover, rather than Cover, but both Richness and Sqrt. Richness could be explored.

The correspondence (r^2, as per cent) between Log Cover and Sqrt Richness was ~43 per cent (Table 3-17), and thus slightly less than one-half of the variance was shared. This might support the factor analysis approach with Multivariate Analyses of Variance.

Correlations between Vegetation Characteristics and Environmental Factors

Following from the correlations among environmental factors or vegetation characteristics, we selected the pairings that appeared most promising. We also undertook all of the possible pairings, and we thus present the key pairings in Table 3-18.

Table 3-18: Pearson product correlation coefficients (*r*) between selected environmental factors and vegetation characteristics, for ~600 vegetation quadrats assessed at four triennial intervals, at twelve Sites along the Duncan Reservoir. Positive correlations of 0.2 or more are in red, while negative correlations, -0.2 or below, are in blue (H = Herb; S = Shrub; Sqrt = square root) (= *p* < 0.01).**

	LogCover	LogHCover	LogSCover	Sqrt Richness
Year	-.257**	-.281**	.034	.014
Location	-.071**	-.063**	-.069**	-.331**
Exposure time	.298**	.218**	.364**	.139**
Substrate	-.307**	-.273**	-.185**	-.185**
Slope	-.260**	-.249**	-.059**	-.242**

Cover is primarily from Herb Cover and both Log Cover and Log Herb Cover were negatively correlated with Year (Table 3-18). This again reflects the decline in vegetation cover after 2009, as was detected in the community analysis from air photo interpretation and the patterns reported for the Overall Reservoir of Results section 4.4. As already recognized, the Exposure time was positively correlated with Cover, including Log Cover, Log Herb Cover and Log Shrub Cover.

Both Log Cover and Log Herb Cover were negatively correlated with Substrate and with Slope (Table 3-18). Thus, vegetation is disfavored with the coarse substrate, which provides an increased substrate texture index. Vegetation is also disfavored by steep Slopes, and this may partly reflect the association between Substrate and Slope since favorable, finer sediments are disfavored on steeper slopes.

Slope was also negatively correlated with species (Sqrt) Richness (Table 3-18) and thus steep slopes disfavor vegetation Cover and Richness. Again, there would be some likely influence through substrate since some of the steep slopes include a very coarse substrate and even bedrock, which is inhospitable for most vegetation. Finally, Richness was negatively correlated with the Site Location, and this reflects the higher Richness at the southern Sites and Locations closer to Duncan Dam, including the Glacier Creek Sites 1 and 2.

These bivariate correlations (Table 3-18) provide guidance for the factor analyses and the subsequent predictive modeling. Those would logically commence with combinations of the environmental factors that were individually correlated with the vegetation characteristics.

3.4.2 Factor Analyses – Multivariate Analyses of Variance

The prior regression and correlation analyses treated the environmental factors and vegetation characteristics as continuous, scalar variables. Those analyses were less suitable for Location since the different Sites varied in a range of characteristics that did not display progressive variation extending upstream from the Duncan Dam. Factor analyses were thus undertaken, and these are better suited for categorical variables such as Location, and also allow for analyses of interactions between factors.

For the factor analyses, as described in the Methods, the continuous variables that were treated as independent factors were binned or grouped. We sought regular groupings relative to the range of observed variation but also selected thresholds where there were breaks in the distribution. We also undertook some merging to provide about 15 groups with fairly similar numbers of members per group to provide sufficiency for analyzing combinations of environmental factors.

We sought common models that would best explain the two vegetation characteristics of Cover (Log Cover) and Richness (Sqrt Richness), and thus undertook Multivariate (Bivariate) Analyses of Variance (MANOVA). The considerable, positive correlation between these two vegetation characteristics (Table 3-17) also supports this approach.

As described in the Methods, the analyses used the SPSS General Linear Model module, with Multivariate analysis to provide the MANOVAs. We assessed the five environmental factors, with the grouped classes for Exposure time, Substrate and Slope. We commenced with each individual factor and then assessed all two and then three factor combinations (Table 3-19).

All of the analyses provided highly significant outcomes ($p < 0.01$). Table 3-19 provides the model fits, with the R^2 for the dependent variables Log Cover and Sqrt Richness. It also shows the Combined outcome with double weighting for Cover since it displayed variation over the decade interval after the implementation of Alt S73. Richness was consistent across the four vegetation surveys (Table 3-17 and Table 3-18).

$$\textbf{Combined } R^2 = ((\textbf{Log Cover } R^2 \times 2) + \textbf{Sqrt Richness } R^2)/3).$$

Table 3-19: Coefficients of determination (R^2) for Cover and Richness and a Combined measure from MANOVAs that investigated effects from 1, 2 or 3 environmental factors that varied across vegetation quadrats in the draw-down zone of the Duncan Reservoir, that were inventoried in four triennial intervals after the implementation of Alt S73. The best fit models are highlighted with bold, red values. The letters in the first column indicate models that are described in the text.

	Year	Location	Exposure Class	Substrate Class	Slope Class		Log Cover	Sqrt Richness	Combined
1 Factor								R^2	
	x						0.089	0.012	0.064
A		**x**					**0.266**	**0.370**	**0.301**
			x				0.113	0.023	0.083
				x			0.112	0.046	0.090
					x		0.127	0.133	0.129
2 Factors									
B	**x**	**x**					**0.413**	**0.407**	**0.411**
	x		x				0.194	0.036	0.141
	x			x			0.301	0.097	0.233
	x				x		0.243	0.149	0.212
		x	x				0.361	0.407	0.376
B		**x**		**x**			**0.362**	**0.479**	**0.401**
		x			x		0.338	0.440	0.372
			x	x			0.240	0.099	0.193
			x		x		0.268	0.244	0.260
				x	x		0.260	0.280	0.267
3 Factors									
	x	x	x				0.529	0.475	0.511
C	**x**	**x**		**x**			**0.531**	**0.532**	**0.531**
	x	x			x		0.530	0.516	0.525
	x		x	x			0.403	0.186	0.331
	x		x		x		0.390	0.270	0.350
	x			x	x		0.472	0.385	0.443
C		**x**	**x**	**x**			**0.480**	**0.541**	**0.500**
		x	x		x		0.443	0.490	0.459
		x		x	x		0.461	0.547	0.490
D			x	x	x		0.490	0.477	0.486
			Elevation	x	x		0.452	0.470	0.458
Exclude Site 13			x	x	x		0.446	0.475	0.456
Exclude Bare Quads			x	x	x		0.469	0.427	0.455
	Year								
E	2009	x	x	x			0.758	0.688	0.735
	2012	x	x	x			0.488	0.573	0.516
	2015	x	x	x			0.527	0.578	0.544
	2018	x	x	x			0.637	0.567	0.614
F	2018	x					0.450	0.430	0.443
	2018	x		x			0.580	0.498	0.553

(A) 1 Environment Factor

Location provided, by far, the strongest explanatory variable for both Cover and Richness (Table 3-19). This accounted for about 30% of the vegetation characteristics (Table 3-17) while the other environmental factors accounted for about 10%, or less. Appendix 4 includes the SPSS MANOVA output for the best-fit single environmental factor, Location.

(B) 2 Environmental Factors

With 2 factor MANOVAs, Location continued to provide a primary factor. Its combination with each of the other four factors led to about a 10% improvement in model fit, thus accounting for ~ 40% of the variation (Table 3-19). Its pairing with Year provided the best fit for Cover, with Year, Location and the Year x Cover Interaction displaying highly significant effects (Appendix 4, SPSS MANOVA output for the best-fit two factor model for Cover, which combined Year and Location).

The pairing with Location and Substrate (Class) provided the best two factor fit for Richness (Table 3-19). While Location displayed a strong effect, Substrate alone did not, and instead, the interaction of Location x Substrate was apparently influential (Appendix 4, SPSS MANOVA output for the best-fit two factor model for Richness, which combined Location and Substrate).

(C) 3 Environmental Factors

The addition of a third environmental factor increased the model fit by a further 10%, raising this to about one-half (R^2 = 0.5, 50%; Table 3-19). A number of combinations produced fairly similar outcomes and the combination of Year and Location along with any one of the other three factors, resulted in the highest model fits and particularly the strongest fit for Cover. The combination of Year, Location and Substrate (Table 3-20) may have been marginally better than Year, Location and Slope. The influence of Year is consistent with the observed decline in vegetation Cover over the study decade, while Location was the predominant influence in the one and two factor analyses (Table 3-19). Consistent with the two-factor outcome, the influence of Substrate was apparently due to specific combinations of Substrate and Location, as evidenced by the interaction terms (Table 3-20). Other interactions were also significant, complicating the patterns. The model fits were reduced when interactions were excluded, indicating that these were influential, but the number of significant interactions challenges the interpretation.

The replacement of Year with Exposure time resulted in another effective three factor model, which, apparently, slightly improved the fit for Richness, while the fit for Cover was reduced (Table 3-19). Exposure time did not display a significant effect on Richness alone (Table 3-21) but a significant Location x Exposure interaction again indicates that the different Sites displayed some differences in the response characteristics relative to the other environmental factors. It was notable that there was no significant interaction between Exposure and Substrate, although the apparent three-way interaction further indicates some complexity in the influences of particular environmental combinations.

Table 3-20: SPSS MANOVA output for the best-fit three factor model, which combined Year, Location and Substrate.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	LogCover	781[a]	365	2.14	8.41	.000
	SqrtRichness	967[b]	365	2.65	8.44	.000
Intercept	LogCover	599	1	599	2351	.000
	SqrtRichness	907	1	907	2892	.000
Year	LogCover	39.1	3	13.0	51.2	.000
	SqrtRichness	6.40	3	2.13	6.80	.000
Location	LogCover	120	11	10.9	42.9	.000
	SqrtRichness	292	11	26.6	84.7	.000
SubstrateClass	LogCover	9.84	16	0.615	2.42	.001
	SqrtRichness	5.68	16	0.355	1.13	.318
Year * Location	LogCover	26.9	33	0.814	3.20	.000
	SqrtRichness	25.6	33	0.776	2.48	.000
Year * Substrate	LogCover	22.2	46	0.482	1.89	.000
	SqrtRichness	16.0	46	0.347	1.11	.288
Location * Substrate	LogCover	61.1	114	0.536	2.10	.000
	SqrtRichness	98.5	114	0.864	2.76	.000
Year * Location * Substrate	LogCover	53.7	141	0.381	1.50	.000
	SqrtRichness	81.8	141	0.580	1.85	.000
Error	LogCover	515	2021	0.255		
	SqrtRichness	634	2021	0.314		
Total	LogCover	3333	2387			
	SqrtRichness	4464	2387			
Corrected Total	LogCover	1296	2386			
	SqrtRichness	1601	2386			

a. R Squared = .603 (Adjusted R Squared = .531)
b. R Squared = .604 (Adjusted R Squared = .532)

Table 3-21: SPSS MANOVA output for a near best-fit three factor model, which combined Location, Exposure time and Substrate.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	LogCover	813[a]	677	1.20	4.25	.000
	SqrtRichness	1074[b]	677	1.59	5.15	.000
Intercept	LogCover	440	1	440	1556	.000
	SqrtRichness	710	1	710	2303	.000
Location	LogCover	72.8	11	6.62	23.4	.000
	SqrtRichness	215	11	19.5	63.3	.000
ExposureClass	LogCover	17.0	11	1.54	5.47	.000
	SqrtRichness	2.53	11	.230	.746	.695
SubstrateClass	LogCover	9.16	16	.572	2.03	.009
	SqrtRichness	7.60	16	.475	1.54	.077
Location * Exposure	LogCover	63.4	111	.571	2.02	.000
	SqrtRichness	68.0	111	.612	1.99	.000
Location * Substrate	LogCover	60.3	113	.534	1.89	.000
	SqrtRichness	95.2	113	.842	2.73	.000
Exposure* Substrate	LogCover	44.1	145	.304	1.08	.259
	SqrtRichness	49.2	145	.339	1.10	.205
Location * Exposure * Substrate	LogCover	106	264	.402	1.43	.000
	SqrtRichness	108	264	.411	1.33	.001
Error	LogCover	483	1709	.282		
	SqrtRichness	527	1709	.308		
Total	LogCover	3333	2387			
	SqrtRichness	4464	2387			
Corrected Total	LogCover	1296	2386			
	SqrtRichness	1601	2386			

a. R Squared = .628 (Adjusted R Squared = .480)
b. R Squared = .671 (Adjusted R Squared = .541)

(D) 3 Environmental Factors – A Hydrogeomorphic Model (HGM)

Following from our factor analyses of the expanded 2009 data set (Polzin et al., 2010), we had concluded that the combination of three physical environmental factors could enable an effective, hydrogeomorphic model (HGM; Hauer and Smith, 1998). This would represent a model that considers the water regime and the substrate characteristics that enable colonization and growth of riparian plants.

The three-factor model with Exposure time, Substrate and Slope (Table 3-19) provides an HGM and the fit for this model was only a few per cent lower than the highest fit, with the inclusion of Year and Location. Year and Location provide specific times or places, while an effective HGM might be more broadly applicable and less constrained by the specific spatial-temporal context. The model concludes that longer exposure, fine substrate and shallow slopes would favour more abundant and diverse vegetation in the Duncan Reservoir draw-down zones, or more broadly for other river or reservoir riparian zones.

We explored some variations with this HGM, and these conclusions would be similarly applicable for the other three factor models. Exposure time provided a slight improvement relative to Elevation (Table 3-19). This was expected since it is the inundation and exposure pattern that is important, and this is imperfectly correlated with Elevation due to the non-linear patterns of reservoir draw-down and fill.

There was a slight reduction in the model fit if Site 13 was excluded (Table 3-19). This Site is situated near the Duncan River inflow and delta and was quite different than the rest of the Sites. It had a shallower slope and more extensive vegetation, but this was primarily a single species, horsetail. The inclusion of the data from the quadrats at this Site improved the model fit by a few per cent for Cover, while the fit for Richness was unaffected.

The reservoir draw-down zones are relatively sparsely vegetated, and this resulted in numerous Bare quadrats. To investigate whether this diluted the patterns, the analyses were undertaken excluding any quadrats that had no vegetation in any of the four survey years. In contrast to the prospect that these blanks could diminish the models, their exclusion slightly reduced the model fits for both Cover and Richness (Table 3-19). Thus, it was beneficial to include the complete data sets in the factor analyses.

(E) 3 Environmental Factors – By Survey Year

As discussed in the Methods, the study design for this investigation included the reassessments of the same (or nearby) quadrats at four, three-year intervals. This would not present a problem for the lower elevation quadrats that would only support annual plants that were renewed yearly but for the quadrats at higher positions near reservoir shoreline. The same perennial plants could be assessed in sequential surveys, violating the requirement for sample independence.

To remove this challenge from repeated measures, we also undertook the factor analyses with only the quadrats from individual survey years. This would exclude the environmental factor Year, and we present the results from analyses of the best fit three factor model without Year, which included Location, Exposure time and Substrate (Table 3-19). This improved the model fits relative to both Cover and Richness, especially for 2009, with the model approaching an explanation of three-quarters of the variation in vegetation characteristics across the quadrats. This strong fit was consistent with the outcome from the prior analysis of the full set of continuous quadrats along transects that were inventoried in 2009 (Polzin et al., 2010), rather than the subset that included quadrats at the beginning, middle and end of each vegetation or cover band.

The three-factor model fit was substantially reduced for the 2012 results, and some prior analyses have also revealed some differentiation in 2012, possibly associated with the steeper reduction in vegetation after 2009 (Figure 3-17, and Figure 3-18). The model correspondence slightly increased for 2015 and further increased for 2018 (Table 3-19). The analyses of individual years support the environmental influences that were revealed with the analyses of the full, four-year data set and reduce the concern for challenges due to pseudoreplication or neglect for repeated measures.

3.4.3 Predictive Modeling – Multiple Linear Regression

This was the third analytical approach and builds upon the findings from the prior bivariate correlations and the factor analyses. Those revealed that the vegetation characteristics of Cover and/or Richness were associated with the environmental factors: Year, Location, Exposure time, Substrate texture and/or Slope. The factor analysis with MANOVAs assessed Location (Site, with the adjusted sequence) as a categorical rather than scalar variable and if only one factor was considered, Location provided the strongest predictor, accounting for ~30% of the variation in the vegetation characteristics.

For two Factors, the combination of Year and Location provided the strongest fit for Cover, while Location and Substrate provided the strongest fit for Richness. These alternate models provided similar combined outcomes and accounted for ~40% of the variation in the two vegetation characteristics. There were significant interactions and thus vegetation varied with specific combinations of Location and Year, or Substrate.

The consideration of three environmental factors improved the model fit to about one half (50 per cent) with various combinations resulting in similar combined correspondences. The factor analyses supported the consideration of the same five environmental factors that provided significant individual correlations with the vegetation characteristics of Cover and/or Richness. The factor analyses included a range of two factor interactions, and while these contributed to the overall model fit for the observed field vegetation patterns, the inclusion of particular interactions would be less practical for prospective future environmental combinations related to dam operations or deliberate mitigation or enhancement measures. To provide predictive modeling for future considerations, we applied multiple linear regression.

It is notable that Ennis et al. (2006) applied a similar multiple linear regression approach for modeling of vegetation around the Arrow Lakes Reservoir. The application of similar modeling approaches increases the comparability of analyses and results from these two nearby reservoirs, which were somewhat similarly created by the flooding of segments of the river and natural lakes, following the implementation of Columbia River Treaty dams.

The Multiple Linear Regression (MLR) was undertaken, and we considered all of the environmental factors, including Elevation and Aspect, but focused on the five environmental factors that were assessed as most important in the bivariate correlation and factor analyses. As a regression approach, we included the specific values for the environmental factors for each quadrat, rather than the classes or groupings, which were used for the factor analyses with MANOVAs.

Site conversions - from Site Location to Site Rank

Site Rank assumed that vegetation characteristics can be influenced or linked to characteristics exhibited from prior years (i.e., historic or legacy influences) that correspond to Location. Some Locations were more or less favorable for the growth of riparian vegetation (Figure 3-15) and this would likely involve site-specific hydrogeomorphic factors and aspects such as seed or propagule sources, which were not assessed in this study.

In preparation for the Multiple Linear Regression to assign Site Rank, we undertook the conversion indicated in Table 2-4 to resequence the Sites by descending average Cover of the quadrats at each Site. This provided a progressive decline and unit spacing provided an excellent linear fit (Figure 3-37, 98 per cent) and thus the simple ordinal numbering (ranking) was appropriate. The more productive sites were in the Peninsula zone (Sites 3, 4, 5), near the Dam (Sites 1, 2), and especially near the Duncan River delta at the upstream end of the reservoir (Site 13, Location 12, Rank 1). With these historic or legacy influences, future vegetation patterns are likely to reflect historic patterns. To incorporate this influence, we ranked the Sites relative to vegetation Cover in the first Study Year, 2009 (Table 2-4).

With the sequencing, the fifth ranked Site (Site/Location 3) falls below the plotted line and the 2012 value was also below that line. Conversely, the 2015 value is offset upwards from the 2015 line, while the 2018 value fits the line. This revealed additional interannual variation at this Site and suggests that the selected sequencing was appropriate. This conversion from Site Location to Site Rank provided a linear pattern that was suitable for the Multiple Linear Regression modeling.

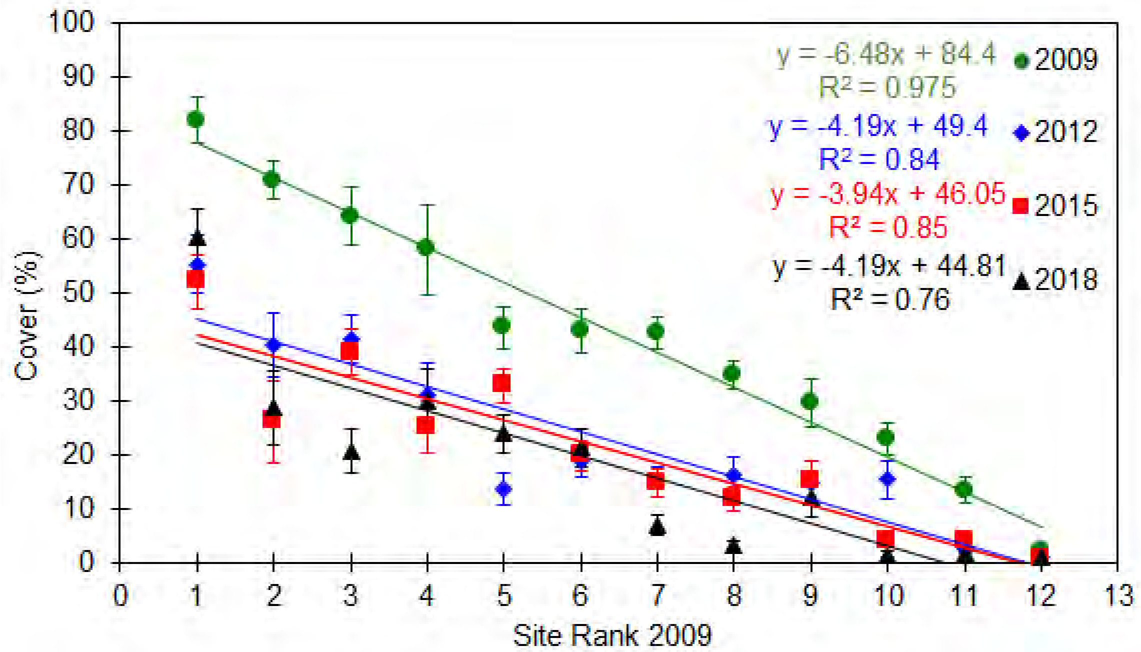


Figure 3-37: Vegetation Cover of the resequenced field study Sites along the Duncan Reservoir, based on the average vegetation Cover of the quadrats at each Site in 2009. Those quadrats were resurveyed in 2012, 2015 and 2018 and those averages are plotted along with corresponding linear regressions that were highly significant ($p < 0.01$).

The plotted lines for the four survey years were generally parallel, with the 2009-line converging towards the other lines for the Sites with sparse Cover. These plots again display the substantial decline in Cover between 2009 and 2012 and then fairly similar vegetation cover in the subsequent study years of 2015 and 2018. While the Site sequencing was based on the 2009 Ranking, the strong linear fits for the subsequent years (84%, 85% and 76%) indicate that the relative extent of vegetation across the Sites was very consistent over the decade interval of the study.

Multiple Linear Regression - Model Parameters

The default MLR in the SPSS Automatic Linear Modeling module applied a forward stepwise approach, which appeared suitable since those outcomes were similar to, or better than model fits with alternate approaches. The model selection applied the Akaike Information Criterion (AIC, with Corrections to provide the AICC) which favors the simplest sufficient model, the model with the fewest factors that provide a near maximal association. Our predictive modeling with MLR assessed Cover and Richness separately, to derive different models that were optimized for the two vegetation characteristics since we considered that there could be different management objectives relative to vegetation Cover versus Richness.

While we used the Automatic Linear Modeling module, we used this for implementation convenience and speed, but we did not adopt the default settings or outcome. Instead, we deliberately explored different model designs and factor combinations. The automated solution recommended Data Preparation to optimize the analyses for both Cover and

Richness. The specific Data Preparation involved a major adjustment, by combining the 2012 and 2015 subsets. However, an emphasis of our study was the contrast across Years, and we had already detected an abrupt vegetation decline from 2009 to 2012 and then a further reduction in vegetation Cover to 2018. Consequently, we rejected the recommendation to merge those two data sets.

The optimized Data Preparations also recommended minor adjustments through the trimming of outliers. However, as evidenced by low Cook's Distance values (only 6 > 0.01, with the maximum being 2 that were ~0.02), the outliers would have limited influence, partly since the data set was fairly large (n = 2,387). The recommended Data Preparation increased the model fit by ~1% for Richness and ~3% for Cover, primarily due to the merging of the two, yearly subsets (Table 3-22). As indicated, we chose to retain the separation of the study years and also included all data. This slightly reduced the fit of the selected models, but the same environmental factors were revealed as being most influential (Table 3-22).

Table 3-22: Results of the Multiple Linear Regression for vegetation characteristics of quadrats in the drawdown zones of the Duncan Reservoir. The proportional importance, which sum to 1.0, are provided for highly significant ($p < 0.01$) factors. The selected models for Cover and Richness, with each factor providing ≥ 5% contribution (Importance ≥ 0.05), are highlighted in bold red.

	Year	Rank	Exposure	Substrate	Slope		Adjusted R^2
		Importance					
Cover*	0.38	0.41	0.18	0.03			37.9
Cover	0.29	0.48	0.20	0.03			34.8
Cover	**0.23**	**0.60**	**0.17**				**34.3**
	2009	0.76	0.24				41.8
	2012	0.72	0.20	0.08			24.0
	2015	0.89	0.11				24.9
	2018	0.40	0.40	0.20			37.6
Herb Cover	0.30	0.70					31.2
Shrub Cover			0.93	0.07			9.9
Richness		**0.94**		**0.06**			**27.7**

Cover – Multiple Linear Regression

Since the SPSS module implemented transformations, Cover rather than Log Cover was analyzed. The initial model run recognized four of the five environmental factors as contributing significantly ($p < 0.01$), but the influence of Substrate was slight, with 3% Importance. We consequently selected the three factor MLR model, which sequentially incorporated the Site Rank (60% Importance), which was apparently as influential as the second and third most Important factors, study Year (23%) and Exposure time (17%) combined.

For this MLR analysis of Cover, the distribution of Studentized Residuals reasonably approximated a normal distribution, indicating the suitability of this statistical approach (Figure 3-38). The selected, 3-factor, forward stepwise model (Automated Data Preparation Off; Information Criterion 15,755) explained slightly more than one-third of the variation across the study quadrats over the decade of repetitive vegetative inventory (34.3%, Table 3-22).

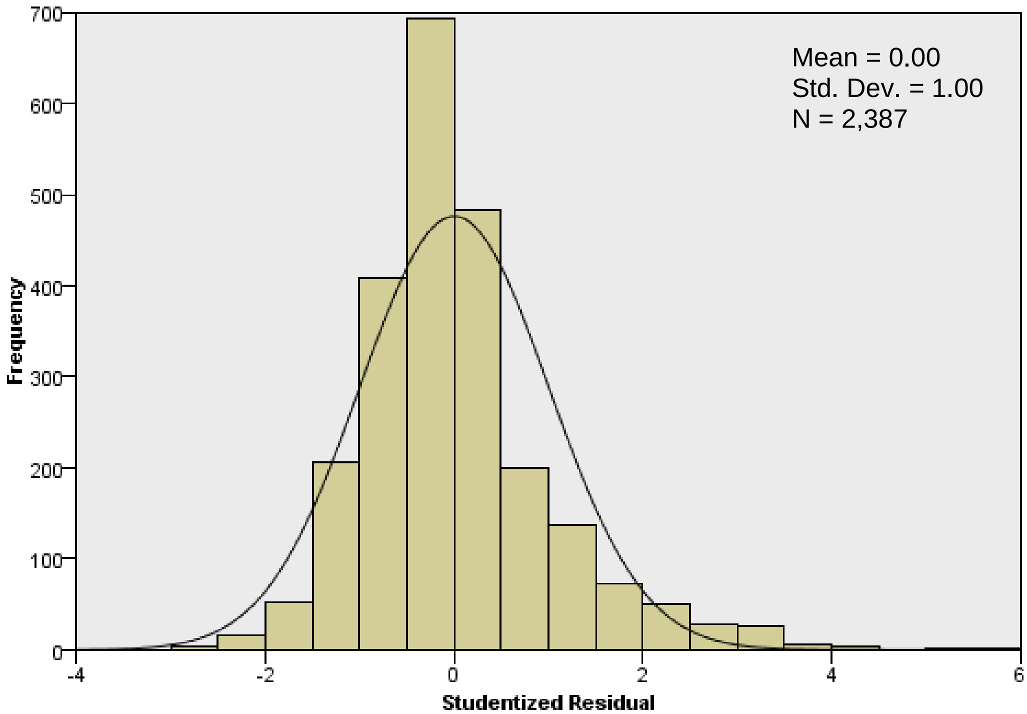


Figure 3-38: Histogram of the Studentized residuals from the selected three factor Multiple Linear Regression model for vegetation Cover in drawdown zones of the Duncan Reservoir. The smooth line represents the normal distribution and as shown the distribution of the residuals reasonably matches this pattern.

With the selected, three factor MLR model, the coefficients for the compound equation are provided in Table 3-23, along with confidence intervals. With these, the predictive equation follows:

Cover (%) = 4828 + (-4.28 x Rank) + (-2.38 x Year) + (0.205 x Exposure Days).

Table 3-23: Multiple Linear Regression coefficients for the selected, three factor model for vegetation Cover in drawdown zones of the Duncan Reservoir.

					95% Confidence Interval		
Model Term	Coefficient	s.e.	*t*	Significance	Lower	Upper	Importance
Intercept	4828	314	15.4	0.000	4213	5443	
Rank	-4.28	0.17	-24.8	0.000	-4.61	-3.94	0.60
Year	-2.38	0.16	-15.3	0.000	-2.69	-2.08	0.23
Exposure	0.205	0.016	13.0	0.000	0.174	0.236	0.17

For interpretation, as with the Hydrogeomorphic (HGM) Model from the factor analysis, this can provide some projection of likely responses to different combinations of prospective future conditions. The most influential factor relative to the vegetation Cover was determined to be the Site Rank. Thus, future vegetation would likely be more extensive at drawdown sites or positions which had substantial vegetation in prior years.

Relative to the second most influential factor, Year, also as with the HGM Model, this effect may have particularly reflected an abrupt, stepwise transition between 2009 and 2012. This could represent an initial temporal effect, which followed the implementation of the Alt S73 dam operation regime (January 2008). The effect was diminished after 2012 and prospectively into the near future. This interpretation is supported by an MLR analysis that excluded the 2009 results. This reduced the MLR model fit to 28.9% and changed the importance of factors. Rank remained the most important (0.62), but Year was unimportant (0.01). Exposure increased in Importance (0.27) and Substrate rose to provide the third most important Factor (0.10). This MLR model would then provide an HGM model, with factors that affected the water and substrate status providing influential contributions.

As with the factor analysis, this MLR approach is somewhat confounded by pseudoreplication of repeated measures, since the quadrats were repetitively assessed at the triennial intervals. Similar to our factor analysis, we undertook the MLR analyses by individual study year, as indicated in Table 3-22. This excluded Year as a contributing factor and the remaining two factors from the multiple year model remained as the next most important predictors. The contribution from Site Rank increased for the data subsets for 2009, 2012 and 2015, but was reduced for 2018. Exposure time was the other important factor, and for the 2018 survey, Exposure matched Rank in the MLR Importance. For 2018, Substrate emerged as a substantial predictor, and Substrate had some influence in 2012.

The model fit was higher for 2009 than for the full multiple year model, accounting for more than 40% of the variation across the 2009 quadrats (Table 3-22). The fit declined sharply for 2012, consistent with the factor analysis, and this could again reflect greater variation accompanying the vegetation decline after 2009. The MLR model fit apparently increased slightly for 2015, even with two rather than three factors. Subsequently the three-factor model for 2018 provided an increased fit that exceeded the multiple-year-model and approached the 2009 model.

Vegetation Cover represented the combined contribution from the herbaceous plants and the larger shrubs, while the contribution from the even tree component was minor in the zones up to the full pool shoreline. Interestingly, different environmental factors were associated with the Herb Cover versus the Shrub Cover (Table 3-22). The Herb Cover provided, by far, the greater contribution to total Cover. Herbaceous Cover was predominantly associated with the prevalence, the factors of Rank (70%) and Year (30%) which were similar to the two primary factors for total Cover. In contrast, Shrub Cover was predominantly influenced by the Exposure time (93%), with a modest influence from Substrate (Table 3-22). These only provided limited model correspondence (10%) and the shrubs were limited to the narrow band within about 3 m below the full pool shoreline. The differing influences on Herb Cover (Rank and Year) versus Shrub Cover (Exposure) combined to provide the three influences on total Cover (Year, Rank and Exposure, Table 3-22).

Richness – Multiple Linear Regression

Unlike Cover, Richness displayed slight changes over the decade long study interval (Figure 3-25). Like Cover, Site Rank provided the strongest influence on Richness, but without the temporal pattern the influence of Rank was substantially higher (94 per cent, Table 3-22). Thus, Sites with diverse vegetation communities retained the diversity over the study interval. There was a slight influence from Substrate (6 per cent, Table 3-22), with increased Richness with finer sediments. The selected two factor MLR model for Richness accounted for slightly more than one-quarter of that variation. Coefficients are provided in Table 3-24 producing the combined equation:

Richness (number of plant taxa) = 3.458 + (-4.28 x Rank) + (0.230 x Substrate).

Thus, the predictive modeling through Multiple Linear Regression worked well following the conversion from Site Location to Site Rank. For vegetation Cover and Richness, the primary influence was from the Site Rank and thus, Sites with considerable vegetation in 2009 had quadrats that were more likely to have increased vegetation Cover and richness in the sequent years. There was an abrupt decline in vegetation Cover after 2009 and after that, Exposure time provided a substantial influence, with longer exposure favoring increased vegetation Cover. Substrate provided a significant, but more modest influence, with finer sediments favoring both Cover and Richness.

Table 3-24: Multiple Linear Regression coefficients for the selected two factor model for vegetation Richness in drawdown zones of the Duncan Reservoir.

					95% Confidence Interval		
Model Term	Coefficient	s.e.	*t*	Significance	Lower	Upper	Importance
Intercept	3.458	0.094	36.648	0.000	3.273	3.643	
Rank	-4.28	0.012	-28.869	0.000	-0.362	-0.316	0.945
Substrate	0.230	0.033	6.968	0.000	0.165	0.294	0.055

3.4.4 Ordination

Free ordination was used to look for a pattern using NMS which allows for analysis on datasets that are highly heterogeneous or have non-linear relationships among responses which our data was tested resulting in the identification of NMS as the appropriate model form. Two main matrices were used, sampling unit by Site and by Transect. The response variable was the mean vegetation over for the 18 dominant species identified for the four sampling years (2009, 2012, 2015, and 2018). The genus species code was modified to fit the PC-ORD format for labels. The change involved using the first 3 letters of the genus and the first three letters of species with no separator between them. Thus, for example, Equi_arv became Equarv.

The ordination by site had the explanatory matrix (2nd matrix) with vegetation types grouped as:

- Wetland consisted of Equarv – horsetail, and Carspp – sedge species combined,
- Riparian consisted of Poptri T (black cottonwood greater than 2 m tall (T)), Poptri S (less than 2 m tall and greater than 50 cm tall (S)), Corsto S and T – red-osier dogwood, and Salspp S – willow species combined, no *Salix exigua* occurred on the reservoir along sampling transects; and

- Weedy species consisted of Cervul – mouse-eared chickweed, Collin – narrow-leaved collomia, Chealb – lamb's-quarters, Eryche – wormseed mustard, Pollap – green smartweed, and Rumcri – curly dock.

Slope was the average slope for the site which remained the same for all years of the study. Substrate and wood vectors were the averages for the sites for individual years. Figure 3-39 shows sites in relationship to the dominant species. The NMS analysis resulted in a 2-dimentional solution with the two axes shown.

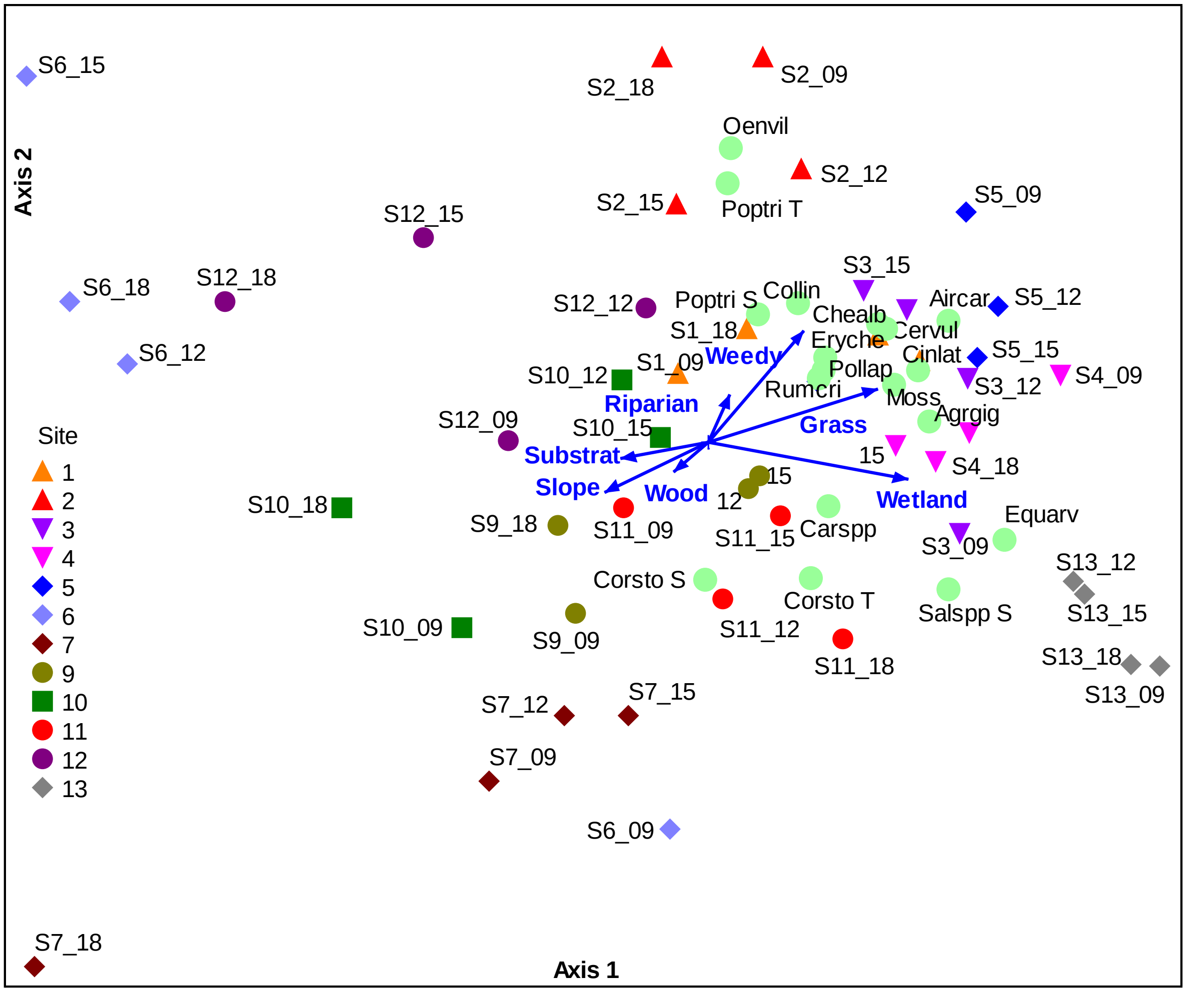


Figure 3-39: Nonmetric multidimensional scaling analysis (NMS) plot showing ordination of sites for the four years with environmental and vegetation type vectors. The vectors are the averages for each site by the year.

The vectors strongest association with axes and R^2 values are:

- Slope – Axis 1 – $R^2 = 0.18$;
- Substrate – Axis 1 – $R^2 = 0.15$;
- Wood – Axis 1 – $R^2 = 0.06$;
- Grass – Axis 1 – $R^2 = 0.30$;
- Riparian – Axis 2 – $R^2 = 0.08$;
- Wetland – Axis 1 – $R^2 = 0.35$; and
- Weedy – Axis 2 – $R^2 = 0.20$.

The coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space are Axis 1, cumulative $R^2 = 0.52$, and Axis 2, cumulative $R^2 = 0.69$.

Vegetation types were further grouped to include ‘other’ type. This was made for the two species that were not part of the other vegetation types (moss and evening primrose). The individual species were then grouped by the vegetation types (second matrix). See Figure 3-40 illustrates the results. Figure 3-40 shows the vegetation species and growth form without the sites to reduce the graph clutter. The grouping by vegetation types illustrates similar results as the two-way cluster analysis.

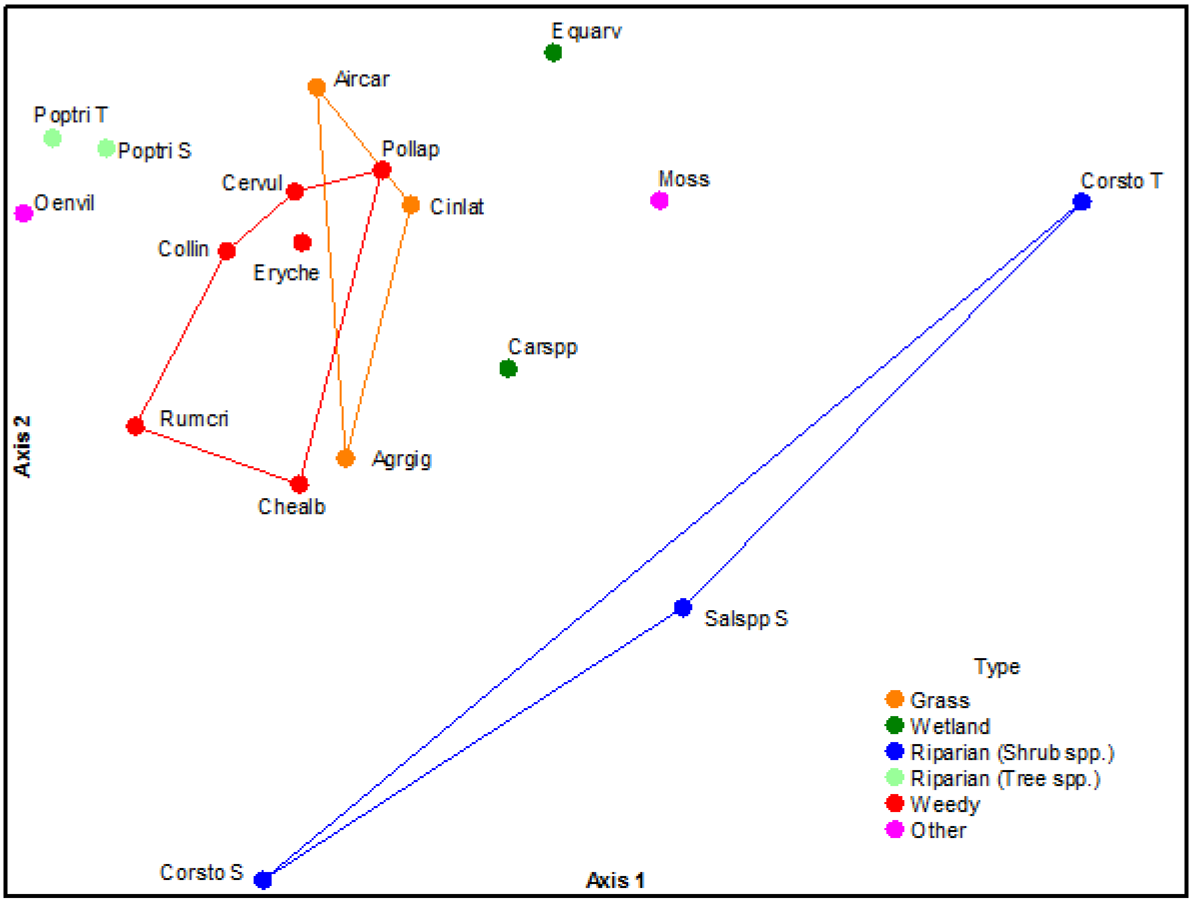


Figure 3-40: NMS dominant species as the sampling unit and site as the response for the 4 study years grouped by vegetation type. The S or T after the species code is the size of plot it was recorded in (S = Shrub plot, woody species <2 m tall and T = Tree plot, woody species >2 m tall) and thus the growth form.

Two-way cluster analysis shows the grouping of the dominant species and Sites across four sampling years (Figure 3-41). The matrix coding shows darker shades of gray representing high vegetation cover by that species for a particular site and year. The numbers (maximum 9) are an additional reference. Lightly shaded squares with no number had trace cover by the species with 1 representing low cover.

The grass community type overlapped the weedy species Pollap and was closely associated with the other weedy species grouping. The sedges (obligate wetland species) are grouped with the facultative riparian common horsetail. The riparian woody vegetation is loosely grouped together with evening primrose (Oenvil) and moss. Both of the herbaceous species were found in areas with higher ground moisture content from seeps or shading by woody vegetation.

Sites were mixed across years with some sites next to each other for two different years. Site 13 was the exception with all four years grouped together (Figure 3-41). Sites 1, 2, 3, 6, and 7 had three years grouped together and the remaining sites had two years grouped.

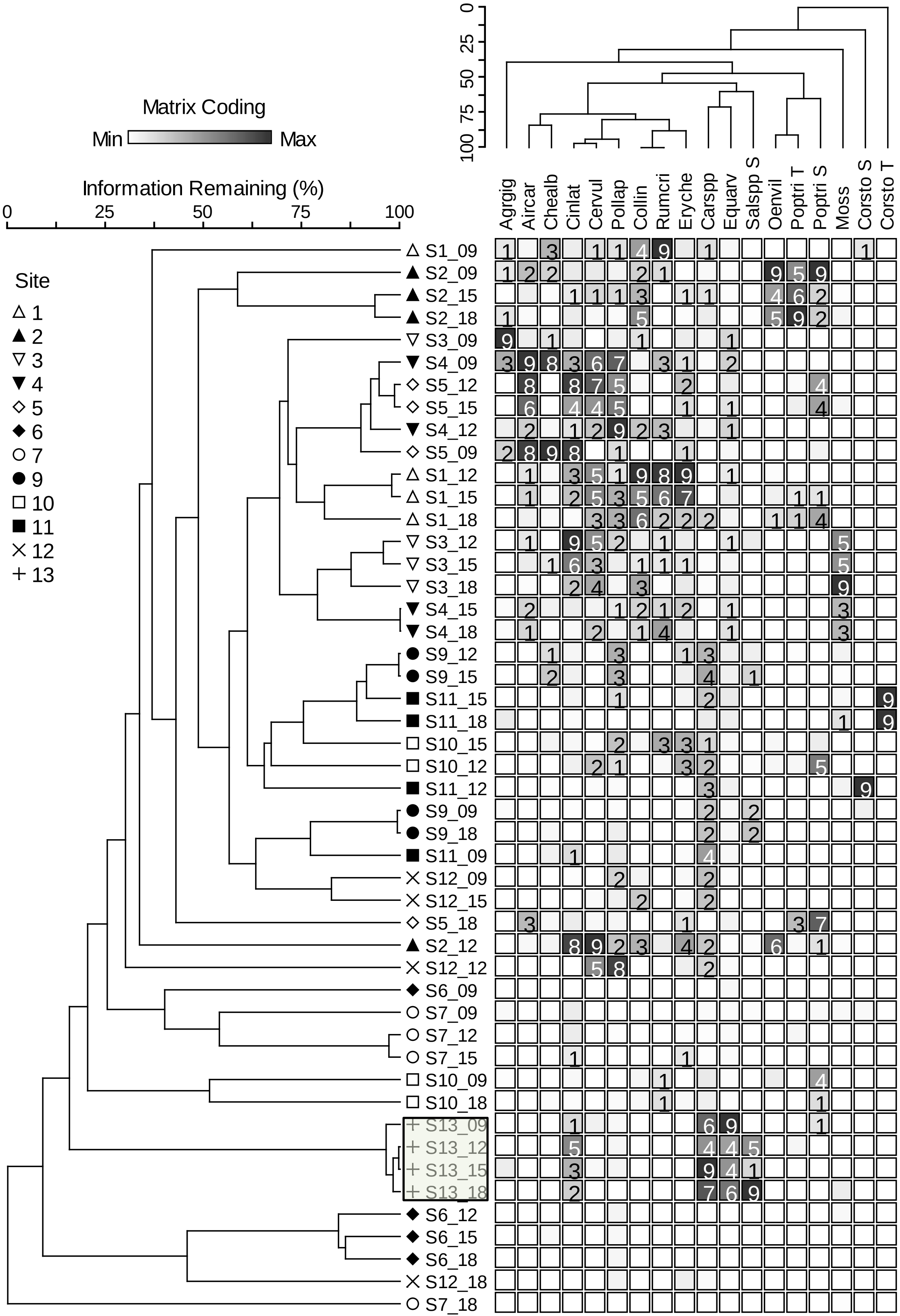


Figure 3-41: Two-way cluster analyses for the dominant species (including different growth forms for the same species) and the four study years.

4.0 DISCUSSION

The Duncan Dam was the first of four large dams that followed the 1964 Columbia River Treaty between the United States and Canada. It was completed in 1967 and is managed by BC Hydro as part of the integrated Columbia River Basin facilities and enables the storage of water in the Columbia Mountains headwater region, north of Kootenay Lake. The Duncan Dam and the other dams are operated primarily for flood flow attenuation and for hydroelectric power generation. Currently, there is no hydroelectric facility at the Duncan Dam, but the released water passes through an extensive sequence of hydroelectric facilities on the Kootenay River and then downstream along the Columbia River through Washington and Oregon, USA.

To assess the environmental and economic impacts and opportunities from the Duncan Dam, the Water Use Planning (WUP) process commenced in 2001 and was completed by 2005. Changes in dam operation with Alternative S73 (Alt S73) were intended to benefit fish and wildlife habitat especially along the Lower reach of the Duncan River, downstream of the Duncan Dam. The improved wildlife habitat was anticipated from benefits to colonization of black cottonwoods and subsequent development of the riparian woodlands. However, the associated changes in the seasonal patterns of fill and drawdown of the Duncan Reservoir were predicted to have negative impacts on the reservoir riparian vegetation in the drawdown zone.

The implementation of Alt S73 prompted in this ten-year study. The DDMMON#8-2 monitoring of the reservoir was undertaken to assess the riparian vegetation in the Duncan Reservoir drawdown zones with a management question:

Will the implementation of DDM WUP result in neutral, positive, or negative changes to riparian vegetation communities within the drawdown zone for the Duncan Reservoir?

The study specifically tested two null hypotheses:

- H_{01}: Alt S73 will not result in decreases to the area or alterations in the species composition of wetland and riparian vegetation communities; and
- H_{02}: Reservoir elevations do not affect riparian distribution and abundance (cover) through the duration and frequency of root- and shoot-zone flooding.

The study involved twelve sites that were selected based on their increased favourability for riparian vegetation, and were primarily located at tributary creek outflows, which had created alluvial fans. The Sites were assessed in 2009, 2012, 2015 and 2018 using two inventory methods. First, plant communities or cover types were mapped through interpretation of aerial photographs, with field assessment for community characterization. Second, repetitive field surveys of vegetation were conducted using quadrats along transects that extended from the full pool shoreline down into the reservoir drawdown zone. All plants were identified, and cover contributions were estimated. From these, the total Cover and species Richness were determined for quadrats, transects, and Sites. The Results section provides more detailed outcomes and with this Discussion section, the major patterns are described.

4.1 Decreased Vegetation Cover after 2009

The analyses related to the first null hypothesis, H_{01}, which anticipated no change in the area of riparian vegetation following the change in the Duncan Dam operation that commenced around 2008 was clearly rejected, with consistent outcomes from the two study components.

From the air photo interpretations, there were reductions in the areas with herbaceous plant communities from 2009 through 2018. The patterns for the twelve sites are presented in Figure 3-9 and Figure 3-10 and reveal major reductions for ten sites. One site (6, Little Glacier Ck.) was almost barren through the full study interval and the site near the Duncan River delta (13, Puddingbowl Ck.) displayed only a slight reduction in vegetation cover. The changes involved transitions of the major zones from sparse vegetation to trace vegetation (Figure 3-12), while the lower, barren zones, higher zones with shrubs or intermediate zones with horsetail (*Equisetum*) were relatively unchanged.

The field survey study confirmed the decline in vegetation cover and indicated a more abrupt loss of vegetation from 2009 to 2012 and then a gradual decline through 2015 and to 2018 (Figure 3-15). The vegetation decline was considerable, with the average cover in the quadrats dropping by almost one-half, primarily due to the loss of herbaceous vegetation. Consistent with the air photo assessment, shrub and tree zones were limited to the highest band near the full pool shoreline and these were relatively constant over the decade of the study.

The greater loss of vegetation from 2009 to 2012 may reflect the initial impacts from the change in reservoir regime. Subsequently, the vegetation patterns were more similar in years 2015 and 2018 and system might have been approaching a new equilibrium, following the implementation of Alt S73

While the cover of riparian vegetation decreased during the study interval, there was little change in the species richness, the number of different plant species. This is related to the second component of H_{01}, which relates to species composition, which was relatively unaltered.

4.2 The Influence of Reservoir Drawdown and Fill – Inundation versus Exposure

The study results also led to the rejection of the second null hypothesis, H_{02}, which proposed that elevation and inundation would not influence vegetation distribution and cover. There were clear elevational patterns at the study sites, with consistent thinning of vegetation moving downward in the reservoir drawdown zone (Figure 3-21). This pattern was consistent across the sites and was also displayed over the sequential samplings from 2009 through to 2018.

While elevation was clearly revealed as an environmental factor that was strongly associated with vegetation cover and richness. Exposure time, the number of growth season days that the location was not inundated, provided an even stronger association with some vegetation characteristics (Figure 3-28). Thus, elevation was important since it was associated with the extent of inundation versus exposure. Lower positions in the drawdown zones were more extensively inundated, and only ruderal annual plants were able to survive with the limited exposure times. Moving upwards along the reservoir banks, the exposure time progressively increased and this allowed perennial plants (Figure 3-24) and subsequently woody plants, including shrubs, and in the highest band near the shoreline, trees.

Inundation versus exposure provided a major environmental influence on the vegetation cover and richness in the reservoir draw-down zones. This provides the primary consequence from the change in the operational regime of Duncan Dam. With Alt S73 there were fewer intervals or years with substantial reservoir drawdown, and this was predicted to reduce vegetation in those drawdown zones. Both study components, air photo interpretation and field inventory with transects and quadrats, supported this prediction.

4.3 Hydrogeomorphic Models – Water and Substrate

The field study also explored the associations between different environmental factors and vegetation characteristics of cover and richness. In addition to the influences of year and exposure time, substrate texture and slope also displayed significant influences. Finer sediments including smaller gravels and sands especially promoted vegetation cover and increased the range of plants that occurred. This would provide a more favorable substrate, since the finer sediments drain slowly and provide capillarity to raise groundwater to the root zone, especially for the vulnerable seedlings.

Shallow slope was also beneficial for the riparian vegetation cover and richness and this would partly act through interactions with substrate. Steeper slopes were commonly very coarse and even included bedrock, which was unfavorable for vegetation. Finer sediments are flushed off from steep slopes either by the reservoir patterns and wave action, or with rain, snow, ice and even wind.

These relationships enabled hydrogeomorphic (HGM) models, which considered the environmental factors that influence water availability and the soil substrate (Table 3-20 and Table 3-21). The models are mechanistic and ecophysiological, and consequently somewhat predictive. The models contribute towards the prescription of management alternatives that could enhance riparian vegetation and provide contributions to wildlife habitat and even the aquatic food web.

The Duncan Reservoir is situated in a humid, temperate climate ecoregion with a limited growth season and substantial precipitation. Weather conditions also influence the water availability and growth conditions for riparian vegetation and climate and weather must also be considered relative to modeling and reservoir management.

4.4 Environmental Factors – Site and Rank

The extent and diversity of riparian vegetation varied dramatically across the twelve study sites. These sites had been pre-selected as apparently favorable sites for reservoir vegetation. As we observed the complete reservoir shorelines over the decade, we consider that these sites were suitably selected and that these generally represented the most favorable areas for riparian vegetation in the reservoir drawdown zones.

Across the sites, there were no clear longitudinal patterns relative to favourability for riparian vegetation cover (Figure 3-17). There was a stronger pattern for richness (Figure 3-19), with higher richness in the southern sites, closer to Duncan Dam (Figure 3-20). This may reflect proximity to seed sources, with more diverse vegetation communities downstream of Duncan Dam, as well as with introduced plants, including weeds, which are more common in the developed areas of the broader floodplain and river valley downstream of Duncan Dam.

The relative rankings across the sites were highly consistent over the study decade (Figure 3-37). Thus, favourable sites remained favourable, even with the vegetation decline after 2009 and the interannual variation in weather, as well as the reservoir fill and drawdown patterns. This finding suggests that there would be a limited prospect for vegetation enhancement in barren sites and conversely, efforts to promote vegetation could emphasize locations that supported substantial vegetation. There would be some challenges or trade-offs with this strategy since the more extensively vegetated sites such as at Glacier Creek are also the preferred locations for recreational use, with cabins, docks and shoreline use including recreational vehicles. Competing land uses also apply for some of the zones along the peninsula but are less applicable for sites at the more remote, north end of the reservoir.

4.5 Puddingbowl Creek – An Unusually Productive Study Site

The most northern study site in the reservoir drawdown zone, at the alluvial fan from Puddingbowl Creek, was the most extensively vegetated site (pages 81-86; Site 13, Location 12, Rank 1). This site was unusual with a very shallow slope and consequently an extensive area that was exposed with slight lowering of the reservoir level (Figure 3-11).

Prior to the Duncan Dam, this Pudding Creek Site had an extensive riparian shrub community along the Duncan River (personal communication with local residents that camp at this site every spring prior-to and after the Duncan Dam installation, and during DDMMON#8-2 monitoring). Installation of the dam resulted in the loss of most of this riparian shrubland. Prior to Alt S73, the remaining shrub community that was on the alluvial fan near the full pool shoreline may have been declining. During and the decade-long study there was apparently some re-establishment within the upper 1 m of the drawdown zone from 576.7 m (full pool elevation) to 575.7 m. There was also some apparent shrub expansion on the flat, floodplain just above full pool. However, throughout the study, this Pudding Creek Site differed from the other sites relative to the drawdown zone and the upland transition zone.

For the Puddingbowl Creek site, Figure 4-1 shows the site with the reservoir at full pool. The vigorous shrubland community on the floodplain bench above the woody debris includes three species of willow, alder, and red-osier dogwood as the dominant shrub species, and juvenile black cottonwood trees. This willow shrubland and flat bench was unique and in contrast, the remaining 11 sites along the reservoir supported conifer-dominated mature upland forest on the steeper slopes, with mature western red cedar, mountain hemlock, and Douglas-fir trees.

The shoreline zone displays the extensive woody debris, which is typical for many shorelines along the Duncan Reservoir. The shallow, inundated zone supports extensive, inundation-tolerant horsetail (inundated in this photo), which provided 71.4 per cent cover for Site 13.

Figure 4-1: An aerial view of the Puddingbowl Creek Site, with the Duncan Reservoir at full pool. The exposed zone has vigorous shrubland with willows and other shrubs and juvenile black cottonwood trees. (July 30, 2018, S. Rood; the report cover photo also displays this site).

This ancient, vascular but spore forming plant, was assessed as common horsetail, *Equisetum arvense.* Around the Arrow Reservoir, Enns et al. (2007) found common horsetail and also reported water (swamp) horsetail (*E. fluviatile*) and marsh horsetail (*E. palustre*). Marsh horsetail is commonly found in nutrient rich wet meadows, rather than the characteristically nutrient impoverished riparian zones. Wood horsetail (*E. sylvaticum*) was identified between the Duncan River main channel and Kootenay Lake in back-levee depressions. It is found in lower-nutrient conditions compared to marsh horsetail. However, the identification of the different *Equisetum* species is difficult and there are variations in the taxonomic treatments.

Horsetail was abundant at some other sites in addition to Puddingbowl Ck. and was the most abundant plant overall across the study sites. The horsetail species are highly inundation tolerant and appear very well suited to the shallow, drawdown zones of the Duncan Reservoir. Horsetail is rich in silica, which results in abrasive shoots, and horsetail is poisonous to some herbivores, including horses, due to the production of thiaminase, which degrades thiamin (vitamin B1). With persistent roots and clonal fragments, the plant is notoriously difficult to control and has been assigned as a weed in many North American regions including British Columbia (*BC. Weed Control Act*).

Relative to regional wildlife, horsetail can provide a substantial component of the diet for black and grizzly bears, but palatability is low for deer and elk (FEIS). In the seasonally inundated zones, it would likely contribute fixed carbon to the aquatic food web, providing a substantial benefit for the impoverished reservoir that lacks a productive littoral zone for fish habitat (Zwart et al. 2011, DDMMON-10).

4.6 The Duncan River Delta – An Expanding Riparian Wetland Complex

An emerging theme in river science is the recognition that along reservoirs, inflow deltas can provide ecologically rich environments that may provide some of the same habitats as were lost with reservoir flooding (Volke et al. 2015). The delta zones are typically fairly flat and as the river flows approach the reservoir slack water, suspended sediments are deposited. This can block that channel and result in flow redirection and channel splitting, producing branched distributaries. The outcome is a complex and dynamic configuration with flowing, blocked and abandoned channels, along with oxbows and other ponds, and extensive and diverse wetland riparian zones. The inflowing river (Figure 4-2) provides abundant water and the vegetation is thus less reliant on the reservoir water than other zones around the reservoir.

The Duncan River Delta at the north end of the Duncan Reservoir displays this type of development and provides the largest riparian wetland complex associated with the reservoir (Figure 4-3). The upper reach of the Duncan River is free-flowing and with the high elevation snowfields and glacial melt, it has reliable flow through the warm and dry interval of mid- to late summer. The river enters the Duncan Reservoir and has created a delta complex that somewhat resembles the natural delta where the lower Duncan River flows into Kootenay Lake.

In the Duncan Reservoir delta, there is a complex mix of herbaceous and especially woody plants, with abundant willows and alder shrubs, and black cottonwood trees. The distributions of the plants reflect the inundation tolerances with the riparian forest tapering off as the delta blends into the reservoir. With sediment deposition, the islands and bars are aggrading. This will continue and enable ongoing expansion of the delta into the reservoir and progressive colonization to ensure a healthy woodland population, with plants ranging from seedlings to mature trees.

Figure 4-2: An upstream view of the Duncan River from the bridge at the north end of Duncan Reservoir. The turquoise color is due to rock flour with glacial melt and the turbid water along the bank is from BB Creek (July 30, 2018, S. Rood).

Figure 4-3: **A downstream-facing, aerial view of the delta zone where the upper Duncan River flows into the Duncan Reservoir. This ecologically rich wetland, riparian and river complex has formed following the flooding of the Duncan Reservoir. It provides riparian woodland and shrub zones, along with ponded areas and saturated wetlands, and would be worthy of environmental protection (July 30, 2018, S. Rood).**

5.0 CONCLUSION

Consistent with the past reports, vegetation cover in the drawdown zone of Duncan Reservoir has been declining since 2009. Both the air photo interpretations and the field surveys were consistent for rejecting the H_{01} which anticipated no change in the area of riparian vegetation following the change in the Duncan Dam operation. The air photo interpretation and the field surveys indicated substantial loss of vegetation cover from 2009 to 2012, followed by gradual decline through 2015 and 2018. These results indicated that the Alt S73 regime has had a negative impact on the riparian vegetation communities, as was expected following the WUP. These findings address the management question related to the environmental impact from Alt S73 on the reservoir ecosystem.

If Alt S73 continues, there could be further reduction in vegetation cover in the deeper band of the reservoir drawdown zone, which extend from around 3 to 10 m below full pool. Alternately, the vegetation distribution could be approaching an equilibrium with the new, Alt S73 flow regime. Seasonal variation in reservoir inundation will continue to influence the vegetation in the drawdown zones, with increasing cover in the spring of each year, before inundation accompanies the reservoir filling in late June. There will also be continuing variation across years, reflecting the variations in river and creek inflows that influence reservoir filling. Those inflows are also correlated with weather that varies across years, with combinations of higher precipitation and runoff often accompanying cooler conditions and both water status and temperature will influence the reservoir vegetation.

Vegetation species richness, the number of plant species, was relatively unaltered by the change in reservoir regime with Alt S73. However, there was some variation in the species composition of a few of the vegetation communities through the decade-long study period. For some communities, the proportional representation changed, resulting in transitions in the dominant, or most abundant plant species after 2009. This was apparent for the wetland sedge and rush vegetation communities. Two grass species, a perennial (nodding wood-reed) and an annual (silvery hair-grass), became dominant communities in 2012 and 2015, respectively. Additionally, two weedy species, wormseed mustard and mouse-eared chickweed, became dominant communities in 2012. One sparse community, juvenile cottonwoods less than 50 cm tall, occurred at some sites and represented 0.03 ha in 2009. This minor community was almost absent thereafter. This would provide the establishment, or pioneer stage for the cottonwood forest communities and the lack of seedling recruitment would exclude the replenishment of this deciduous tree that generally provides the foundation for the riparian forest community in the Columbia River Basin.

Changes to community composition and decreases to species cover were probably largely due to the reservoir fill and drawdown regime of Alt S73 but also partly due to the environmental variation, especially in the spring weather patterns over the ten-year study period. The analyses confirmed the importance of the inundation regime, but also reveal other important influences.

The reduction in the perennial riparian community species and the increase in weedy annual community species (mainly at the lower elevations) could be viewed as a negative change to the riparian vegetation communities within the drawdown zone. There was a slight but positive change, with a minor increase in shrub and tree cover close to the full pool margin after 2009. However, this was substantially due to the expansion of willows particularly at Site 13, near the north (inflow) end of the reservoir (discussion following). The increase in shrub and canopy cover also reflected the growth of woody plants that had established before the implementation of Alt S73, including some shrubs and trees that were established through clonal expansion from parental willows or cottonwoods along or slightly above the shoreline. If Alt S73 continues, or with a reversion to the prior operational regime, there could be a continued increase in density of woody vegetation in a narrow band at the top 1 to 2 m of the drawdown zone. However, without recruitment of new willows and cottonwoods that woodland band would not be rejuvenated, and there would be limited structure, the vertical diversity that provides habitats for different birds and other wildlife. Further, over a time-frame of around a century there could be forest succession, with conifers replacing the cottonwoods.

Vegetation was also sparse or absent in the upper elevation zones near the full pool shoreline in locations where woody debris occurred. The woody debris covered the surface, excluding seedling colonization and plant growth, and its movement with wave action scours the vegetation and the surface sediments. Wave action alone, such as with wind-driven waves or from boat wakes, provides some erosive scour of sediments and vegetation but the tossing of woody debris produces a much more powerful disturbance. This provides an indirect influence from the raised reservoir, and the impact is avoided when the reservoir is lower.

The repeated ground-level monitoring in the Duncan Reservoir drawdown zones in 2009 to 2018 rejected the H_{02} that anticipated elevation would not affect the riparian distribution and cover through the duration and frequency of root-zone flooding. Multivariate modeling revealed that the vegetation cover was positively associated with the exposure time, which is the inverse of the duration of inundation from reservoir flooding. Exposure versus inundation is determined by the elevational position in the drawdown zone, and the groundwater status is also influenced by substrate texture, with sandy gravels providing capillary rise. The analyses confirmed that that extended shoot and root-zone flooding impeded riparian vegetation, as has been repeatedly observed for other drawdown reservoirs.

The extent and diversity of vegetation varied across the study sites that were primarily on alluvial fans that occurred along the full length of the reservoir. For factor analyses, conversion from Site Location to Site Rank based on the vegetation abundance, revealed the importance of historic or legacy influences, with different zones being more or less favourable for riparian vegetation. Ranking sites resulted in strong linear fits for subsequent years (84, 85, and 76 per cent) which indicated that the relative extent of vegetation across the sites was very consistent over the decade interval of the study. Some consistency would reflect perennial vegetation, with multiple year life-spans but the annual plant also displayed consistency across the sites. The variation across sites would reflect different environmental conditions, including substrate texture and slopes, along with supplemental surface and groundwater from inflowing creeks, and other consistent factors such as proximity to seed sources.

Thus, sites with considerable vegetation in 2009 had quadrats that were more likely to have increased vegetation cover and richness in the sequent years. This analysis resulted in selecting Site Rank as a primary factor in Multiple Linear Regression (MLR) models.

The optimal MLR model for vegetation cover included three factors, Site Rank, Year, and Exposure, which combined to explain about one-third of observed variation across quadrats. The resulting predictive model equation was:

Cover (%) = 4828 + (-4.28 x Rank) + (-2.38 x Year) + (0.205 x Exposure Days).

The optimal MLR model for Richness, included Site Rank and Substrate texture, and accounted for about one-quarter of the observed variation. The resulting predictive model equation was:

Richness (number of plant taxa) = 3.458 + (-4.28 x Rank) + (0.230 x Substrate).

Site 13, at the north (inflow) end of the reservoir, was adjacent to the delta from the outflow of the upper Duncan River and displayed a much larger band of riparian vegetation in the reservoir drawdown zone. Site 13 differed from the other sites in the physical conditions, including:

- Very shallow slope extending downward from the full pool shoreline (average 3.7 per cent);
- Subsequently long distances from POC to the -1 m elevation contour - average 45 m for the 3 transects. The sampling format included a maximum transect length of 100 m and at Site 13, this only dropped to 2 or 3 m below full pool, versus the 10 m depth at the other sites with steeper slopes;
- Fine Substrate Texture Index (average of 1.0 in 2018);
- A low Solar-drying index Aspect (two transects had aspects drying index of 1 = N-NE, the lowest and two with an aspect of 3 = NE-E); and
- Adjacent seed source from the delta zone and possible root-sucker propagation of riparian plants, especially willow and cottonwood, from the adjacent, gently sloped alluvial fan.

Woody species (mainly willow) cover at Site 13 contributed slightly more than one-quarter of the total shrub cover for the drawdown zones of the 12 reservoir sites in 2009, similar to that in 2018. This site was thus unusually productive for riparian vegetation.

Thus, in summary and as predicted, the revised reservoir regime with Alt S73, resulted in some vegetation loss around the Duncan Reservoir drawdown zone.

6.0 Management Recommendations

Following the completion of Duncan Dam, the Duncan Reservoir flooded the ecologically rich mosaic of floodplain, wetlands, shallow ponds, and streams that characterized the Duncan River valley which flanked the natural Duncan Lake (Utzig and Schmidt 2011, Rood et al. 2020). In contrast to those rich and biodiverse floodplain zones, the drawdown zones of the Duncan Reservoir are ecologically, relatively barren. Most of the shoreline is characterized by steep banks that extend down into the reservoir and the prior river valley bottom is annually inundated for prolonged intervals, and the annual combination of prolonged inundation and then complete drying is lethal to all plants. In contrast to the predominant steep banks down into the reservoir, the inflowing tributary creeks contribute sediments that create alluvial fans, which provide richer ecological resources, and these were the sites investigated with this ten-year study.

The study revealed decreases in riparian vegetation in the drawdown zones of the alluvial fans after the new Duncan Dam operating regime Alt S73. This decline was predicted prior to the change in operation that was intended to benefit the riparian and aquatic environments downstream of the dam, but with a trade-off of reduced riparian vegetation around the Duncan Reservoir.

The vegetation decline from 2009 to 2012 at least partly reflected the change in the drawdown and fill regime initiated in 2008. The Alt S73 regime provides a more uniform pattern, which lacks the extended intervals with lower reservoir levels. The irregular intervals for lower reservoir levels with the prior dam operation regime may have supported more extensive perennial species cover. If the prior regime was restored, it is likely that there would be some increase in riparian vegetation in the reservoir drawdown zones.

Alternately, there may be some refinements in reservoir level management. It could be beneficial to limit the frequency and duration of inundation of the upper drawdown zones, which could support perennial plants, including shrubs. These are particularly valuable relative to wildlife habitat and contribute to the aquatic ecosystem through leaf and branch litter and the support of invertebrates that contribute to the aquatic food web.

Recommendation

As a management recommendation related to the Duncan Dam operation, it could be beneficial to the riparian and aquatic ecosystems of the Duncan Reservoir to reduce the duration of inundation of the upper drawdown zone, particularly the bands within one to three metres of elevation below the full pool shoreline. This could promote riparian vegetation communities, including the cottonwood forest and riparian shrub bands.

Current technical studies for the renegotiation of the Columbia River Treaty (CRT) provide guidance for this prospective riparian enhancement strategy (Rood et al. 2022). Analyses of the elevational distributions of vegetation and corresponding inundation regimes around Duncan, Arrow, Kinbasket and Koocanusa reservoirs indicate that black cottonwoods could survive in bands with shallow slopes and at elevations with an average of almost four weeks of annual flooding through the growth season of May through October. Willows could survive an annual average of seven weeks of inundation, with some year-to-year variation including occasionally longer flooded intervals for both plant groups. Inundation is less stressful in the spring, when rivers naturally flood, and more stressful in late summer, and has little influence outside of the growth season through winter.

It is recognized that this would influence the flow release regime and thus the multiple consequences would need to be assessed, including the downstream influences on Kootenay Lake and then downstream along the Kootenay River and into the Columbia River system. These could be projected with a coupled hydrological-ecological model that is being developed for the Upper Columbia River Basin, as part of the studies associated with the consideration for renewal of the Columbia River Treaty. That model is intended for this type of application, to assess prospective operational scenarios and the balancing of environmental and economic outcomes.

Considerations outside the Scope of Project

As recognized in Section 1.1, the zone at the upstream, north end of the Duncan Reservoir provides the zone with the most extensive riparian vegetation associated with the reservoir. This includes the alluvial fan near the outflow of Puddingbowl Creek (Site 13) and the ecologically rich and diverse delta where the upper Duncan River flows into the reservoir. This zone is fairly remote and has experienced limited impact. A new road is being developed along the western side of the reservoir and this may lead to increasing access and impact. To avoid environmental impact, some degree of environmental protection could be beneficial.

Recommendation Memo 1. Secure environmental protection for the Duncan River delta zone at the north end of the Duncan Reservoir, possibly in the form of an Ecological Reserve. The protected zone could extend for some distance upstream along the upper Duncan River, to conserve that rich and distinctive riverscape.

The critical habitat loss of wetlands, floodplains, riparian areas, and shallow ponds (46.7 per cent of the area flooded by Duncan Reservoir) within the ecosystem poses challenges for restoration enhancement of the Duncan Reservoir (Utzig and Schmidt (2011). Fish habitat has been decreasing with limited to no littoral zone currently at the reservoir (Zwart et al. 2011). The Duncan Reservoir fill regime is at or within 1 m (576.7 to 575.7 m) of full pool water levels from July 29 to August 26 on average since 2008. This results in a very narrow zone where riparian vegetation may expand. Traditional restoration efforts that are successful at other reservoir drawdown zones require suitable topography and substrate texture that does not occur along the 11 sites monitored during this study, or it occurs in a very narrow band susceptible to woody debris scour. Site 13 (the 12th Site sampled) does not require restoration enhancement.

Recommendation Memo 2. Field trials into alternative new reclamation proposals that:

1. Expand the area that can support and develop into self-sustaining wetland communities without drought-induced mortality when the reservoir lowers;
2. Expand the area that supports and develops into self-sustaining floodplain communities without inundation induced mortality during reservoir fill; and
3. Enhance the fish habitat by providing cover, food, and increased nutrient levels in the water column.

By meeting these three objectives, wildlife and fish habitat is enhanced while restoring some of the lost wetland and riparian habitat and providing an aquatic food chain environment in areas where it is implemented.

7.0 CLOSURE

VAST Resource Solutions trusts that this report satisfies your present requirements. Should you have any comments, please contact us at your convenience.

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Appendix 1: Site Descriptions, Characteristics, Reservoir and Upland Plants Classifications

Site descriptions, characteristics, and possible influences in the drawdown zone of the Duncan Reservoir in 2015. Some tags required replacing resulting in new Transect number identification.

Site #	Side	Aspect	Camp-ground	Main Road Influence	Creek Influence	Transects	
						Tran. #	Length (m)
1	East	SW	Yes	No	No	1	0-320
						700/869	0-134
2	East	NW-W	No	Secondary Rd	No	701/884	0-304
						702/885	0-388
						703/822	0-360
3	East	N-NE	No	No	No	704	0-52
						812	0-48
4	East	NW-W	Yes	No	Yes	705	0-71
		E-SE				706	0-54
5	East	SW-W	No	No	No	707	0-130
						813	0-71
6	East	NW-W	No	Yes	Yes	708	0-101
						814	35
7	East	NW-N	Yes	No	No	2	0-40
						3	0-55
9	East	SW-W	Yes	No	No	709	0-92
			No	No	No	710	0-107
		NW-W				711	0-151
						712	0-168
10	East	NW-W	Yes	No	Yes	6	0-185
		S-SW	No	Yes	No	713	0-90
						714	0-84
11	West	N-NE	No	No	No	715	0-67
			No	No	Yes	716	0-71
12	West	NE-E	No	No	No	5	0-60
						718	0-52
13	West	N-NE	No	No	Yes	717	0-100
						4	0-100
		NE-E				719	0-100
						720	0-100

Reservoir Plants Identified Below Full pool (576.7 m to 566.7 m elevation).

Abbreviations for tables:

Vegetation Classes:	Vegetation Group:	Status:
AG – Annual Grass	NOL – Upland	N – Native
PG – Perennial Grass	UPL – Obligate Upland	E – Exotic
AH – Annual Herb	OBL – Obligate Riparian	(NOX) – Noxious
PH – Perennial Herb	FAC – Facultative	(W) – Weed
WS – Woody Shrub	FACR – Facultative Riparian	(R) – Ruderal
WT – Woody Tree	FACU – Facultative Upland	
M – Moss		
F – Ferns		

Vegetation Group Descriptions

NOL – Upland species that does not occur in wetlands/riparian in another region. It is not on the national list (NOL).

UPL – Obligate upland species that occur in wetlands in another region (estimated probability greater than 99%), but almost always occurs under natural conditions in non-riparian/wetlands in the region specified.

OBL – Obligate riparian species that almost always occurs under natural conditions in riparian zones (estimated probability greater than 99%).

FAC – Facultative species that is equally likely to occur in wetlands/riparian or uplands (estimated probability 34% - 66%).

FACR – Facultative riparian species that usually occurs in riparian/wetland habitat (estimated probability 67% - 99%), but is occasionally found in non-riparian/wetland habitat.

FACU – Facultative upland species that usually occurs in uplands (estimated probability 67% - 99%) but is occasionally found in wetland/riparian habitats (estimated probability 1% - 33%).

(R) – Ruderal species are first to colonize disturbed lands.

(+) & (-) Signs – used with facultative indicator categories to specify frequency toward the higher end of the category (+) more frequently found or the lower end of the category (-) less frequently found.

Traditional Use Plant Species are marked with *

Grass:

Scientific Name	Common Name	Species Code	Veg Class	Status	Veg Group
Agrostis gigantea	redtop	Agro_gig	PG	E	FACR (R)
Aira caryophyllea	silvery hairgrass	Aira_car	AG	E	NOL
Bromus anomalus	nodding brome	Brom_ano	PG	N	FAC
Bromus inermis	smooth broom	Brom_ine	PG	E	FAC+ (R)
Bromus tectorum	cheatgrass	Brom_tec	AG	E (W)	FAC
*Calamagrostis canadensis	blue-joint	Cala_can	PG	N	OBL(R)
Cinna latifolia	nodding wood-reed	Cinn_lat	PG	N	OBL(R)
Elymus repens	quackgrass	Elym_rep	PG	E (W)	NOL(R)
Festuca campestris	rough fescue	Fest_cam	PG	N	NOL
Muhlenbergia richardsonis	mat muhly	Muhl_ric	PG	N	FAC
*Phalaris arundinacea	reed canary grass	Phal_aru	PG	N (W)	OBL
Poa pratensis	Kentucky bluegrass	Poa_pra	PG	E (W)	FAC

Herbaceous:

Scientific Name	Common Name	Species Code	Veg Class	Status	Veg Group
Apocynum androsaemifolium	spreading dogbane	Apoc_and	PH	N	NOL
Aralia nudicaulis	wild sarsaparilla	Aral_nud	PH	N	FACU
Aster conspicuus	showy aster	Aste_con	PH	N	NOL
*Athyrium filix-femina	lady fern	Athy_fil	F	N	FAC
Axyris amaranthoids	Russian pigweed	Axyr_ama	AH	E	FACU
Carex aquatilis	water sedge	Care_aqu	PH	N	OBL
*Carex lasiocarpa	slender sedge	Care_las	PH	N	OBL
*Carex utriculata	beaked sedge	Care_utr	PH	N	OBL
Centaurea maculosa	spotted knapweed	Cent_mac	PH	E(NOX)	UPL (R)
Cerastium vulgatum	mouse-eared chickweed	Cera_vul	AH	N(W)	FACU (R)
Chenopodium album	lamb’s-quarters	Chen_alb	AH	N(W)	FACU(R)
Chrysanthemum leucanthemum	oxeye daisy	Chry_leu	PH	E(W)	NOL(R)
Collomia linearis	narrow-leaved collomia	Coll_lin	AH	N	FACU
Dryas drummondii	yellow mountain avens	Drya_dru	PH	N	FACU
Epilobium angustifolium	fireweed	Epil_ang	PH	N(W)	FACU
*Equisetum arvense	common horsetail	Equi_arv	PH	N(W)	FACR
*Equisetum hyemale	scouring-rush	Equi_hye	PH	N	FACR
Erysimum cheiranthoides	wormseed mustard	Erys_che	AH	N(W)	FACU
Euphorbia esula	leafy spurge	Euph_esu	PH	E(NOX)	FACU
Lappula redowskii	western stickseed	Lapp_red	AH	N	FACU
Matricaria discoidea	pineapple weed	Matr_dis	AH	E(W)	FACU(R)
Medicago lupulina	black medick	Medi_lup	PH	E(W)	FACU
Mimulus guttatus	yellow monkey-flower	Mimu_gut	AH	N	OBL
	All moss species (2012)	Moss spp	M	N	OBL
Myosotis laxa	small-flower forget-me-not	Myos_lax	PH	N	OBL
Oenothera villosa	evening primrose	Oeno_vil	PH	N	FAC

Scientific Name	Common Name	Species Code	Veg Class	Status	Veg Group
Polygonum lapathifolium	green smartweed	Poly_lap	AH	N(W)	OBL
Potentilla diversifolia	diverse-leaved Cinquefoil	Pote_div	PH	N	FAC
Potentilla glaucophylla	diverse-leaved Cinquefoil	Pote_gla	PH	N	FAC
Prunella vulgaris	self-heal	Prun_vul	PH	N	FACR
Pteridium aquilinum	bracken	Pter_aqu	F	N(W)	FACU
Rumex crispus	curly dock	Rume_cri	PH	E(W)	FACR
Taraxacum officinale	dandelion	Tara_off	PH	E(W)	FACU
Trifolium arvense	hare's-foot clover	Trif_arv	AH	E	NOL
Trifolium pratense	red clover	Trif_pra	PH	E(W)	FACU
Trifolium repens	white clover	Trif_rep	PH	E(W)	FACU
Vicia americana	American vetch	Vici_ame	PH	N	FACU

Shrubs:

Scientific Name	Common Name	Species Code	Veg Class	Status	Veg Group
Acer glabrum	Douglas maple	Acer_gla	WS	N	FACU+
Alnus crispa	sitka alder	Alnu_cri	WS	N	FACR
*Amelanchier alnifolia	Saskatoon	Amel_aln	WS	N	FACU
*Arctostaphylos uva-ursi	kinnikinnick	Arct_uva	WS	N	FACU
Berberis aquifolium	Oregon-grape	Berb_aqu	WS	N	FACU
*Cornus stolonifera	red-osier dogwood	Corn_sto	WS	N	FACR
Linnaea borealis	twinflower	Linn_bor	WS	N	FACU-
Lonicera involucrata	black twinberry	Loni_inv	WS	N	FAC
Prunus virginiana	choke cherry	Prun_vir	WS	N	FAC
*Rubus parviflorus	thimbleberry	Rubu_par	WS	N	FAC
*Salix bebbiana	Bebb's willow	Sali_beb	WS	N	FACR
*Salix lucida	Pacific willow	Sali_luc	WS	N	FACR
*Salix scouleriana	Scouler’s willow	Sali_sco	WS	N	FAC
*Shepherdia canadensis	buffalo berry	Shep_can	WS	N	NOL
*Symphoricarpos albus	snowberry	Sym_alb	WS	N	FACU

Trees:

Scientific Name	Common Name	Species Code	Veg Class	Status	Veg Group
Betula occidentalis	water birch	Betu_occ	WT	N	FACR
*Betula papyrifera	paper birch	Betu_pap	WT	N	FACU
Picea glauca x engelmannii	hybrid white spruce	Pice_gla x	WT	N	FACU
Pinus contorta var. latifolia	lodgepole pine	Pinu_con	WT	N	FACU
Populus tremuloides	trembling aspen	Popu_tre	WT	N	FACU
*Populus trichocarpa	black cottonwood	Popu_tri	WT	N	FACR
Pseudotsuga menziessii var. glauca	interior Douglas fir	Pseu_men	WT	N	FACU
*Thuja plicata	western redcedar	Thuj_pli	WT	N	FACU

Upland species sampled from 576.7 m to 578.7 m elevation above full pool. Traditional Use Plants marked with *.

Herbaceous:

Scientific Name	Common Name	Species Code
Agrostis gigantea	redtop	Agro_gig
Agrostis scabra	hair bentgrass	Agro_sca
Apocynum androsaemifolium	spreading dogbane	Apoc_and
Aralia nudicaulis	wild sarsaparilla	Aral_nud
Aster ciliolatus	Lindley's aster	Aste_cil
Calamagrostis rubescens	pine grass	Cala_rub
*Carex utriculata	beaked sedge	Care_utr
Centaurea maculosa	spotted knapweed	Cent_mac
Chenopodium album	lamb’s-quarters	Chen_alb
Chrysanthemum leucanthemum	oxeye daisy	Chry_leu
Cinna latifolia	nodding wood-reed	Cinn_lat
Clintonia uniflora	queen's cup	Clin_uni
Cornus canadensis	bunchberry	Corn_can
Dryas drummondii	yellow mountain avens	Drya_dru
Epilobium angustifolium	fireweed	Epil_ang
*Equisetum arvense	common horsetail	Equi_arv
Equisetum sylvaticum	wood horsetail	Equi_syl
Festuca campestris	rough fescue	Fest_cam
*Fragaria virginiana	strawberry	Frag_vir
Goodyera oblongifolia	rattlesnake plantain	Good_obl
*Gymnocarpium dryopteris	oak fern	Gymn_dry
Hieracium umbellatum	narrow-leaved hawkweed	Hier_umb
Koeleria macrantha	June grass	Koel_mac
*Maianthemun racemosum	false-solomon's seal	Maia_rac
Medicago lupulina	black medick	Medi_lup
Moss spp.	All moss species (2012)	Moss spp
Pleurozium schreberi	Schreber's red stem (moss)	Pleu_sch
Pteridium aquilinum	bracken	Pter_aqu
Taraxacum officinale	dandelion	Tara_off
Trifolium pratense	red clover	Trif_pra
Vicia americana	American vetch	Vici_ame

Shrubs:

Scientific Name	Common Name	Species Code
Acer glabrum	Douglas maple	Acer_gla
Alnus crispa	Sitka alder	Alnu_cri
*Amelanchier alnifolia	Saskatoon	Amel_aln
Arctostaphylos uva-ursi	kinnikinnick	Arct_uva-urs
*Berberis aquifolium	Oregon-grape	Berb_aqu
Chimaphila umbellata	prince's-pine	Chim_umb
*Cornus stolonifera	red-osier dogwood	Corn_sto
Linnaea borealis	twinflower	Linn_bor
Lonicera involucrata	black twinberry	Loni_inv
Lonicera utahensis	Utah honeysuckle	Loni. uta.
*Oplopanax horridus	devil's club	Oplo_hor
*Pachistima myrsinites	falsebox	Pach_myr
Prunus virginiana	choke cherry	Prun_vir
*Ribes lacustre	black gooseberry	Ribe_lac
*Rosa acicularis	prickly rose	Rosa_aci
*Rosa gymnocarpa	baldhip rose	Rosa_gym
*Rubus parviflorus	thimbleberry	Rubu_par
*Salix bebbiana	Bebb's willow	Sali_beb
*Salix lucida	pacific willow	Sali_luc
*Salix scouleriana	Scouler’s willow	Sali_sco
*Shepherdia canadensis	buffalo berry	Shep_can
Taxus brevifolia	western yew	Taxu_bre
*Vaccinium membranaceum	black huckleberry	Vacc_mem
*Vaccinium ovalifolium	oval-leaved blueberry	Vacc_ova

Trees:

Scientific Name	Common Name	Species Code
Abies grandis	grand fir	Abie_gra
*Betula papyrifera	paper birch	Betu_pap
Larix occidentalis	western larch	Lari_occ
Picea glauca	white spruce	Pice_gla
Pinus contorta var. latifolia	lodgepole pine	Pinu_con
Pinus monticola	western white pine	Pinu_mon
Populus tremuloides	trembling aspen	Popu_tre
*Populus trichocarpa	black cottonwood	Popu_tri
Pseudotsuga menziessii var. glauca	interior Douglas fir	Pseu_men
*Thuja plicata	western redcedar	Thuj_pli
Tsuga heterophylla	western hemlock	Tsug_het

Appendix 2: Reservoir Elevation Analyses Table and Plant Community Area Table

Duncan Reservoir elevation analyses for high riparian potential sites identified by BC Hydro (2009) – 2017 growing season.

Week #	***Average Elevation (m)***	**2D surface area above average weekly reservoir elevation by site (m^2 and % of site)**																	
		Site 1		**Site 2**		**Site 3**		**Site 4**		**Site 5**		**Site 6**		**Site 7**		**Site 10**		**Site 13**	
		Area (m^2)	**%**	**Area (m^2)**	**%**	**Area (m^2)**	**%**	**Area (m^2)**	**%**	**Area (m^2)**	**%**	**Area (m^2)**	**%**	**Area (m^2)**	**%**	**Area (m^2)**	**%**	**Area (m^2)**	**%**
1	548.00	60,112.5	*100*	240,242.6	*100*	10,193.2	*100*	139,546.4	*100*	77,153.7	*100*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
2	547.45	60,112.5	*100*	240,242.6	*100*	10,193.2	*100*	139,546.4	*100*	77,153.7	*100*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
3	547.59	60,112.5	*100*	240,242.6	*100*	10,193.2	*100*	139,546.4	*100*	77,153.7	*100*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
4	547.84	60,112.5	*100*	240,242.6	*100*	10,193.2	*100*	139,546.4	*100*	77,153.7	*100*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
5	547.98	60,112.5	*100*	240,242.6	*100*	10,193.2	*100*	139,546.4	*100*	77,153.7	*100*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
6	548.48	60,112.5	*100*	240,242.6	*100*	10,193.2	*100*	139,546.4	*100*	77,153.7	*100*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
7	548.98	60,112.5	*100*	240,242.6	*100*	10,193.2	*100*	139,546.4	*100*	77,153.7	*100*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
8	549.63	60,112.5	*100*	240,242.6	*100*	10,193.2	*100*	139,546.4	*100*	77,153.7	*100*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
9	554.01	60,112.5	*100*	240,242.6	*100*	10,193.2	*100*	139,546.4	*100*	77,153.7	*100*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
10	558.95	58,145.1	*97*	240,242.6	*100*	9,610.2	*94*	139,546.4	*100*	73,457.8	*95*	21,094.2	*100*	5,047.6	*100*	120,070.3	*100*	67,950.8	*100*
11	562.80	40,409.8	*67*	224,158.5	*93*	7,324.0	*72*	134,413.2	*96*	66,677.7	*86*	17,772.8	*84*	5,023.2	*100*	118,733.0	*99*	67,950.8	*100*
12	565.64	28,728.6	*48*	179,144.4	*75*	6,010.6	*59*	96,240.5	*69*	57,344.3	*74*	11,870.5	*56*	4,546.5	*90*	98,769.0	*82*	67,950.8	*100*
13	568.24	18,899.5	*31*	140,603.0	*59*	4,797.0	*47*	66,366.9	*48*	44,947.5	*58*	7,633.2	*36*	3,972.2	*79*	57,469.1	*48*	67,950.8	*100*
14	571.17	11,625.6	*19*	93,750.4	*39*	3,343.3	*33*	34,428.5	*25*	20,055.4	*26*	3,868.8	*18*	3,151.5	*62*	33,453.0	*28*	67,950.8	*100*
15	573.73	5,035.3	*8*	44,947.5	*19*	1,459.8	*14*	14,267.0	*10*	8,495.7	*11*	2,407.5	*11*	2,177.1	*43*	17,621.6	*15*	23,344.1	*34*
16	575.31	1,645.3	*3*	16,799.7	*7*	511.2	*5*	5,165.3	*4*	3,815.9	*5*	1,634.8	*8*	1,336.0	*26*	8,891.6	*7*	5,477.2	*8*
17	576.18	234.1	*0*	3,856.8	*2*	102.7	*1*	2,087.6	*1*	1,642.0	*2*	1,274.3	*6*	688.4	*14*	3,674.7	*3*	814.8	*1*
18	576.38	88.3	*0*	2,347.0	*1*	61.6	*1*	1,675.5	*1*	1,235.4	*2*	1,189.4	*6*	530.8	*11*	2,532.6	*2*	429.0	*1*
19	576.39	82.8	*0*	2,288.1	*1*	59.7	*1*	1,659.1	*1*	1,216.1	*2*	1,185.0	*6*	522.8	*10*	2,476.3	*2*	412.8	*1*
20	576.40	73.2	*0*	2,184.9	*1*	56.4	*1*	1,630.1	*1*	1,181.5	*2*	1,177.0	*6*	508.1	*10*	2,377.6	*2*	384.4	*1*
21	575.90	655.0	*1*	7,200.1	*3*	175.6	*2*	2,824.4	*2*	2,276.1	*3*	1,389.2	*7*	902.9	*18*	5,034.2	*4*	1,748.1	*3*
22	575.54	1,265.9	*2*	13,058.7	*5*	353.7	*3*	4,180.4	*3*	3,203.5	*4*	1,540.6	*7*	1,178.2	*23*	7,093.1	*6*	3,909.1	*6*
23	575.47	1,377.4	*2*	14,169.4	*6*	409.4	*4*	4,467.1	*3*	3,384.8	*4*	1,568.8	*7*	1,226.7	*24*	7,546.0	*6*	4,396.4	*6*
24	575.04	2,134.6	*4*	21,437.9	*9*	640.8	*6*	6,516.0	*5*	4,598.4	*6*	1,750.8	*8*	1,514.5	*30*	10,613.1	*9*	7,257.3	*11*
25	573.98	4,476.9	*7*	40,176.7	*17*	1,283.1	*13*	12,639.8	*9*	7,719.4	*10*	2,279.9	*11*	2,066.5	*41*	16,383.6	*14*	18,848.6	*28*
26	572.93	6,929.3	*12*	61,180.3	*25*	2,080.2	*20*	20,068.0	*14*	11,183.9	*14*	2,804.6	*13*	2,519.1	*50*	22,654.2	*19*	47,031.2	*69*
*85th Percentile**	**576.04**	**425.6**	***0.7***	**5,350.4**	***2.2***	**139.4**	***1.4***	**2,433.3**	***1.7***	**1,949.6**	***2.5***	**1,331.9**	***6.3***	**795.8**	***15.8***	**4,344.7**	***3.6***	**1,227.3**	***1.8***

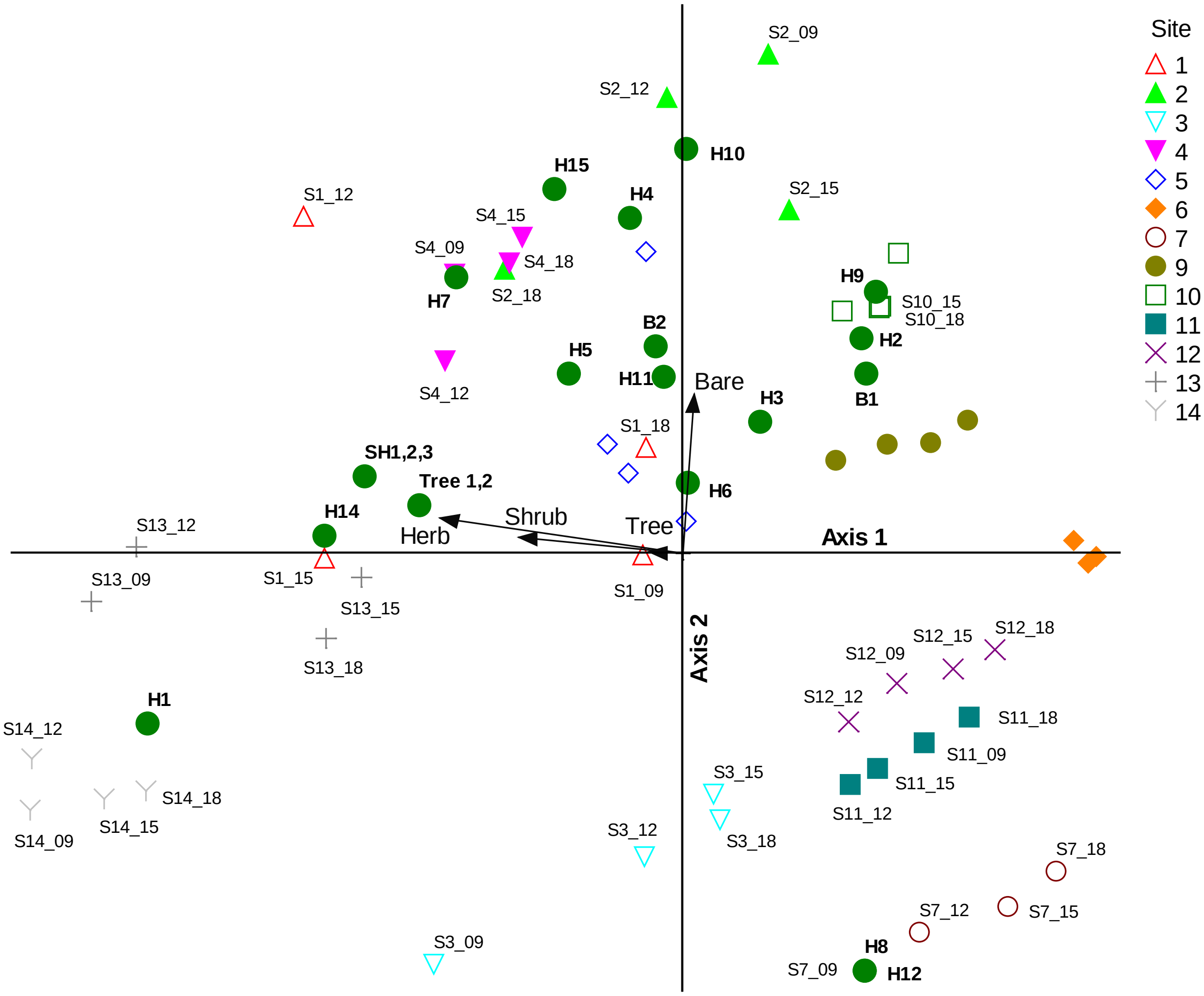
* Represents the elevation at which the drawdown zone is exposed for 85 - 100% of the growing season

Data summaries for areas (ha) of each vegetation type at the sites and total area (ha) for each community. Totals for the previous years were included for comparison.

Veg. Type	**Community ***	**S.1**	**S.2**	**S.3**	**S.4**	**S.5**	**S.6**	**S.7**	**S.9**	**S.10**	**S.11**	**S.12**	**S.13**	**S.14**	**2018 Total**	**2015 Total**	**2012 Total**	**2009 Total**
Bare (ha)	B1 (bare)	0.02			0.25	0.72	1.88	0.44	2.89	8.01	0.93	1.29		0.32	16.75	22.51	16.32	15.56
	B2 (bare, trace vegetation)	4.93	19.54	0.73	6.71	3.25	0.23	0.07	2.61	3.95	0.38	0.51	1.52	0.02	44.43	35.40	7.91	0.11
Bare Total		**4.94**	**19.54**	**0.73**	**6.96**	**3.97**	**2.11**	**0.50**	**5.50**	**11.96**	**1.31**	**1.80**	**1.52**	**0.34**	**61.18**	**57.91**	**24.23**	**15.67**
Shrub (ha)	SH1 (shrub 1, cottonwood <2 m tall)	0.0005	0.10												0.10	0.10	1.43	0.35
	SH2 (shrub 2, willow)								0.001				0.13	0.43	0.57	0.77	0.74	0.64
	SH3 *(shrub 3, other species)				0.003										0.00	0.06	0.59	0.53
Shrub Total		**0.00**	**0.10**		**0.00**				**0.00**				**0.13**	**0.43**	**0.67**	**0.93**	**3.63**	**1.52**
Tree (ha)	TR1 (tree, cottonwood > 2 m tall)	0.004	0.14							0.01					0.15	0.11	0.16	0.0032
	TR2 (tree, other species > 2 m tall)										0.01		0.47	0.23	0.71	0.0060		
Tree Total		**0.004**	**0.14**							**0.009**	**0.006**		**0.47**	**0.23**	**0.86**	**0.12**	**0.16**	**0.00**
Herbaceous (ha)	H1 **(herb 1, common horsetail)		0.37	0.05	0.69	0.79			0.02	0.002	0.012		4.67	18.79	25.40	25.73	26.76	28.58
	H2 (herb 2, sedge species)								0.003						0.00	0.32	1.23	1.40
	H3 (herb 3, green smartweed)															1.81	9.3	11.92
	H4 (herb 4, grasses)																0.72	30.70
	H5 (herb 5, narrow-leaved collomia)	1.06	3.77												4.83	0.12		1.85
	H6 (herb 6, small-flowered bulrush)					0.03									0.03	0.14	0.96	0.15
	H7 (herb 7, lamb's-quarters)																	7.09
	H8 (herb 8, spotted knapweed)																	0.07
	H9 (herb 9, yellow mountain avens)									0.04					0.04	0.04	0.05	0.06
	H10 (herb 10, evening primrose)		0.03												0.03	0.04	0.06	0.03
	H11 ***(herb 11, monkey-flower)				0.03										0.03	0.03	3.14	3.52
	H12 (herb 12, cottonwood < 0.5 m)																	0.03
	H13 (herb 13, nodding wood-reed)		0.09	0.24											0.32	1.51	6.32	
	H14 (herb 14, wormseed mustard)															3.74	0.28	
	H15 (herb 15, chickweed)																25.75	
	H16 (herb 16, silvery hair-grass)				6.27	2.93									9.20	10.16		
Herb Total		**1.06**	**4.25**	**0.29**	**6.99**	**3.75**	**0.00**	**0.00**	**0.02**	**0.04**	**0.01**	**0.00**	**4.67**	**18.79**	**39.88**	**43.63**	**74.58**	**85.40**
Grand Total (= site area)		***6.01***	***24.02***	***1.02***	***13.95***	***7.72***	***2.11***	***0.50***	***5.52***	***12.01***	***1.33***	***1.80***	***6.80***	***19.79***	***102.59***	***102.59***	***102.60***	***102.59***

* The dominant species is listed but up to three were listed on the GIS tables if there were 2nd and 3rd ranking species.
**Facultative (FAC) species that is equally likely to occur in wetlands or non-wetlands
***Wet open areas - Obligate (OBL) annual wetland species
Blue shaded communities are marshy shore wetland communities.
Green is a riparian recruitment zone.
Pale orange shaded areas indicate communities that occurred in previous years but are no longer dominant communities in the year sampled.

Appendix 3: Additional Ordination Graphs



Nonmetric multidimensional scaling (NMS) applied to the area of ground covered by the community for each site for each sampling year. The ordination is on rank order. The vectors indicate the direction of increasing cover and their length reflects the magnitude of the association with ordination axes. The data set used to generate this graph was not reproducible as it had bare ground with the vegetation cover classes. As one increases the other one decreases but the site area remains the same. This is supplied here as a visual aid as it helps to see where the bare ground (B1 and B2) distances occur relative to sites and other vegetation communities. It also shows all sites and all communities with no grouping or deletions.

Vector association to axes were:

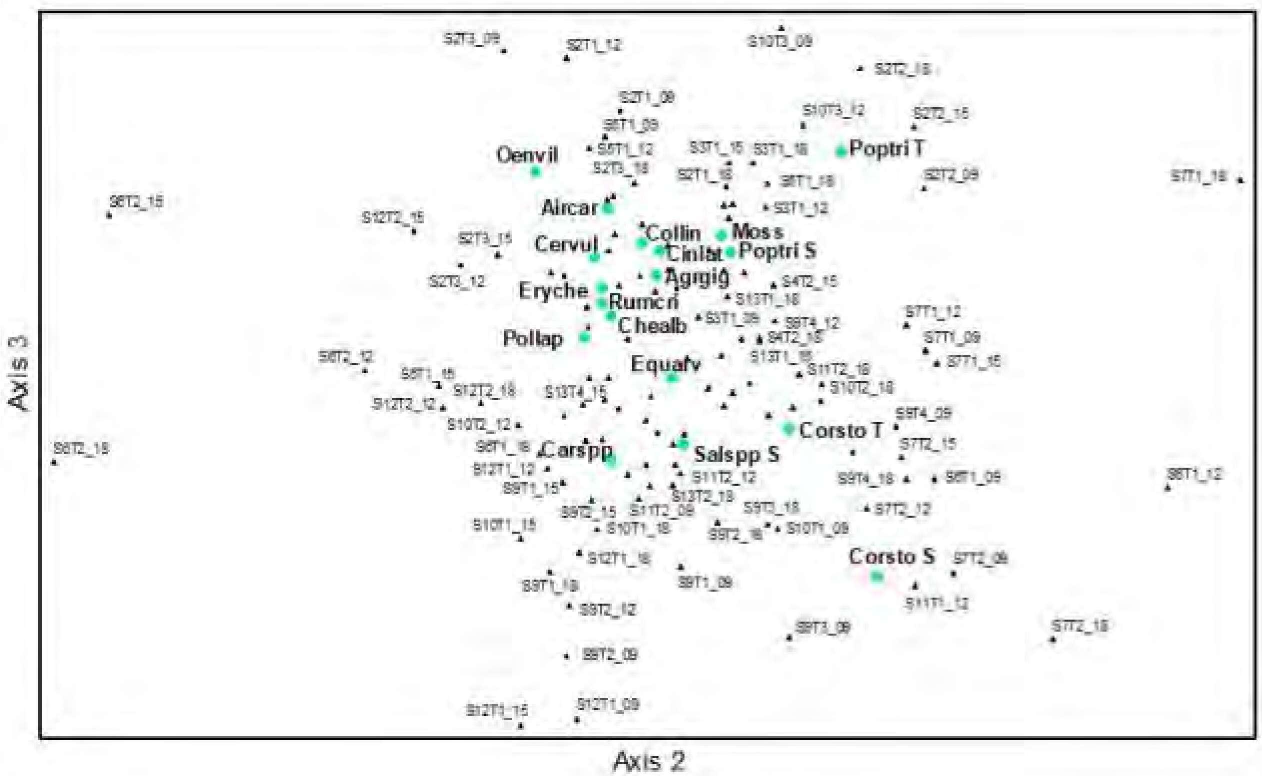
- Bare ground was associated with Axis 2 with an R^2 = 0.30;
- The vegetation communities were associated with Axis 1 with the herb community R^2 = 0.46;
- Shrub community R^2 = 0.31; and
- Tree community R^2 = 0.06.

The 3-dimentional axes R^2 are:

- Axis 1 – R^2 = 0.31;
- Axis 2 – R^2 = 0.23; and
- Axis 3 – R^2 = 0.19.

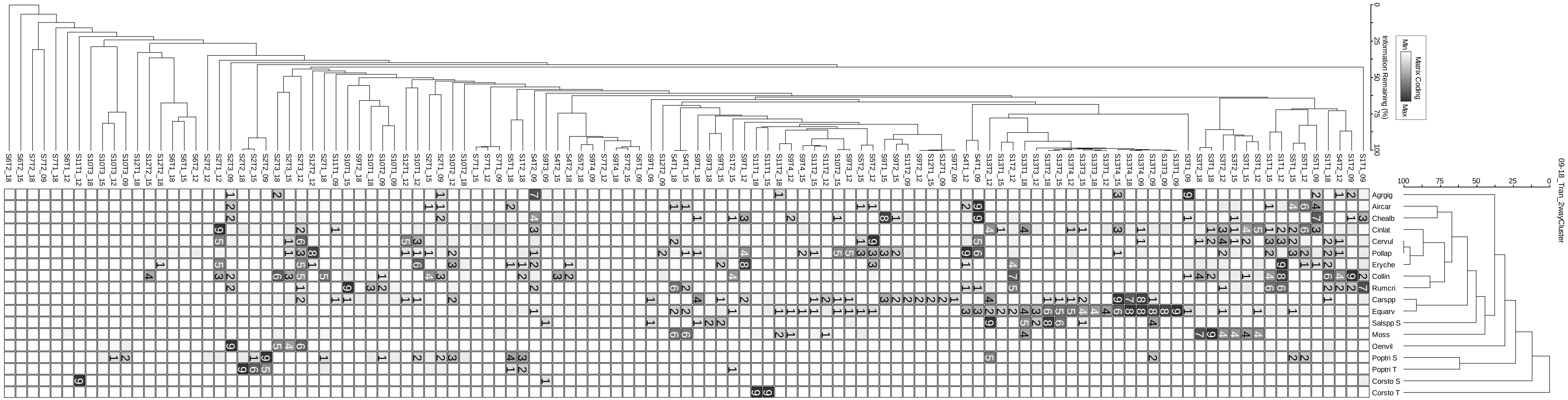
Because axes 1 and 2 were the highest R^2 values the communities were graphed on these two axes.

NMS analysis by transects and the 4 years resulted in a 3-dimension solution. It is similar to sites with shifts in positions occurred between the same transects but in different years. Because of the numerous data points the graph was not used in the report but is supplied here for reference.



The two-way cluster analysis was also completed and is supplied for reference as it shows a similar pattern as Site and is very large due to the increase in data.

Two-way cluster analysis by transect for the 4 years of the project with 18 dominant species for the response variable.



Appendix 4: Statistical Analyses Tables

Map Area versus years

One sample t test testing 09 mean for grass area to 2012, 2015, and 2018

For 2012 G= grass area combined to match 2009

Group Name	N	Missing	Mean	Std Dev	SEM		
G_Area_12	11	0	0.64	1.136	0.343		
Hypothesized population mean			4.38				
t = -10.915 with 10 degrees of freedom.							
95 percent two-tailed confidence interval for the population mean: -0.123 to 1.403							
Two-tailed P-value = 0.000000709							
There is a statistically significant difference between the mean of the sampled population and the hypothesized population mean (P = <0.001).							
One-tailed P-value = 0.000000354							
The hypothesized mean exceeds the sample mean of the group by an amount that is greater than would be expected by chance, rejecting the hypothesis that the true mean of the group is greater than or equal to the hypothesized mean. (P = <0.001).							
Power of performed two-tailed test with alpha = 0.050: 1.000							
Power of performed one-tailed test with alpha = 0.050: 1.000							

For 2015

Group Name	N	Missing	Mean	Std Dev	SEM		
G_Area_15	11	0	1.06	2.229	0.672		
Hypothesized population mean			4.38				
t = -4.939 with 10 degrees of freedom.							
95 percent two-tailed confidence interval for the population mean: -0.438 to 2.558							
Two-tailed P-value = 0.000588							
There is a statistically significant difference between the mean of the sampled population and the hypothesized population mean (P = <0.001).							
One-tailed P-value = 0.000294							
The hypothesized mean exceeds the sample mean of the group by an amount that is greater than would be expected by chance, rejecting the hypothesis that the true mean of the group is greater than or equal to the hypothesized mean. (P = <0.001).							
Power of performed two-tailed test with alpha = 0.050: 0.993							
Power of performed one-tailed test with alpha = 0.050: 0.998							

For 2018

Group Name	N	Missing	Mean	Std Dev	SEM		
G_Area_18	11	0	0.866	1.993	0.601		
Hypothesized population mean			4.38				
t = -5.847 with 10 degrees of freedom.							
95 percent two-tailed confidence interval for the population mean: -0.473 to 2.205							
Two-tailed P-value = 0.000162							
There is a statistically significant difference between the mean of the sampled population and the hypothesized population mean (P = <0.001).							
One-tailed P-value = 0.0000811							
The hypothesized mean exceeds the sample mean of the group by an amount that is greater than would be expected by chance, rejecting the hypothesis that the true mean of the group is greater than or equal to the hypothesized mean. (P = <0.001).							
Power of performed two-tailed test with alpha = 0.050: 0.999							
Power of performed one-tailed test with alpha = 0.050: 1.000							

Testing all communities with Tree, Bare ground, and Grass communities grouped

Friedman Repeated Measures Analysis of Variance on Ranks

Data source: Data 1 in Ho1 testing_Reservoir.JNB

Group	N	Missing	Median	25%	75%
2009	18	0	0.438	0.0319	4.415
2012	18	0	0.665	0.0375	4.115
2015	18	0	0.111	0.0235	1.030
2018	18	0	0.0266	0.000	0.641

Chi-square= 15.847 with 3 degrees of freedom. (P = 0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

Tested individually, 2015 to 2018 has P = 0.004 all the rest are P = >0.001

One-Sample t-test

Group Name	N	Missing	Mean	Std Dev	SEM
%bare	2	0	58.000	2.263	1.600

The hypothesized population mean 15.300 2009 % bare ground

t = 26.687 with 1 degree of freedom.

95 percent two-tailed confidence interval for the population mean: 37.670 to 78.330

Two-tailed P-value = 0.0238

There is a statistically significant difference between the mean of the sampled population and the hypothesized population mean (P = 0.024).

One-tailed P-value = 0.0119

The sample mean of the group exceeds the hypothesized mean by an amount that is greater than would be expected by chance, rejecting the hypothesis that the hypothesized mean is greater than or equal to the true mean. (P = 0.012).

Power of performed two-tailed test with alpha = 0.050: 0.964

Power of performed one-tailed test with alpha = 0.050: 1.000

One-Sample t-test

Group Name	N	Missing	Mean	Std Dev	SEM
%Veg	2	0	41.958	2.256	1.595

The hypothesized population mean 84.700, 2009 veg % area for communities

t = -26.790 with 1 degrees of freedom.

95 percent two-tailed confidence interval for the population mean: 21.686 to 62.230

Two-tailed P-value = 0.0238

There is a statistically significant difference between the mean of the sampled population and the hypothesized population mean (P = 0.024).

One-tailed P-value = 0.0119

The hypothesized mean exceeds the sample mean of the group by an amount that is greater than would be expected by chance, rejecting the hypothesis that the true mean of the group is greater than or equal to the hypothesized mean. (P = 0.012).

Power of performed two-tailed test with alpha = 0.050: 0.964

Power of performed one-tailed test with alpha = 0.050: 1.000

NMS stress tests in relation to dimensionality for the number of axes and if there is a detectible pattern in the data.

STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)							
	Stress in real data			Stress in randomized data			
	50 run(s)			Monte Carlo test,		50 runs	
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
1	29.653	49.442	55.866	0	46.108	55.839	0.0784
2	18.05	18.834	20.343	0	22.07	29.348	0.0784
3	11.834	12.636	29.883	0.01	14.327	17.818	0.0392
4	9.277	9.822	23.106	0.016	10.554	23.953	0.1373
p = proportion of randomized runs with stress < or = observed stress							
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)							
Conclusion: a 3-dimensional solution is recommended.						Run 1 Auto medium	

STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)							
	Stress in real data				Stress in randomized data		
	250 run(s)				Monte Carlo test, 250 runs		
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
1	29.649	49.086	56.059	0	46.174	56.005	0.0837
2	18.05	18.982	30.628	0.001	22.709	30.303	0.0558
3	11.835	12.391	29.808	0.001	14.326	17.902	0.0478
4	9.272	9.599	24.13	0.004	10.292	12.63	0.0837
5	7.399	7.737	19.036	0.011	8.013	20.737	0.1195
6	5.861	6.218	17.45	0.015	6.322	17.256	0.1195
p = proportion of randomized runs with stress < or = observed stress							
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)							
Conclusion: a 3-dimensional solution is recommended.						Run 2 Auto slow	

STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)							
	Stress in real data				Stress in randomized data		
	250 run(s)				Monte Carlo test, 250 runs		
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
1	30.971	47.16	55.952	29.205	47.114	55.935	0.0392
2	17.88	19.664	38.8	20.121	23.915	29.882	0.0196
3	11.686	11.977	15.115	12.281	14.906	18.155	0.0196
4	9.187	9.438	10.098	9.264	10.796	13.136	0.0196
p = proportion of randomized runs with stress < or = observed stress							
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)							
Conclusion: a 3-dimensional solution is recommended.						Run3 Auto slow	

STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)							
	Stress in real data				Stress in randomized data		
	250 run(s)				Monte Carlo test, 250 runs		
	------------------------	----------------------------------					
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
1	30.971	47.16	55.952	29.205	47.114	55.935	0.0392
2	17.88	19.664	38.8	20.121	23.915	29.882	0.0196
3	11.686	11.977	15.115	12.281	14.906	18.155	0.0196
4	9.187	9.438	10.098	9.264	10.796	13.136	0.0196
p = proportion of randomized runs with stress < or = observed stress							
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)							
Conclusion: a 3-dimensional solution is recommended.						Run4 Auto medium	

Not on auto, set at 3 dimensions using a random seed.

STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)							
	Stress in real data			Stress in randomized data			
	50 run(s)			Monte Carlo test,	50 runs		
	------------------------	----------------------------------					
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
--							
1	29.65	47.322	56.049	0	46.27	56.011	0.0558
2	18.05	18.899	21.454	0	23.035	38.83	0.0438
3	11.835	12.339	29.587	0.001	14.469	28.334	0.0478
--							
p = proportion of randomized runs with stress < or = observed stress							
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)							
Conclusion: a 3-dimensional solution is recommended.						Set at 3 dimensions	

Test 2

STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)							
	Stress in real data			Stress in randomized data			
	50 run(s)			Monte Carlo test,	50 runs		
	------------------------ -	----------------------------------					
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
--							
1	30.971	47.16	55.952	29.205	47.114	55.935	0.0392
2	17.88	19.664	38.8	20.121	23.915	29.882	0.0196
3	11.686	11.977	15.115	12.281	14.906	18.155	0.0196
4	9.187	9.438	10.098	9.264	10.796	13.136	0.0196
--							
p = proportion of randomized runs with stress < or = observed stress							
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)							
Conclusion: a 3-dimensional solution is recommended.						Set at 3 dimensions	

Test 3

STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)		

	Stress in real data			Stress in randomized data			
	50 run(s)			Monte Carlo test,		50 runs	
	-----------------------	----------------------------------					
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p
--							
1	30.971	47.16	55.952	29.205	47.114	55.935	0.0392
2	17.88	19.664	38.8	20.121	23.915	29.882	0.0196
3	11.686	11.977	15.115	12.281	14.906	18.155	0.0196
4	9.187	9.438	10.098	9.264	10.796	13.136	0.0196
--							
p = proportion of randomized runs with stress < or = observed stress							
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)							
Conclusion: a 3-dimensional solution is recommended.						Set at 3 dimensions	

Area_NMS_Oct17-%variance				
Coefficients of determination for the correlations between ordination				
distances and distances in the original n-dimensional space:				
	R	Squared		
Axis	Increment	Cumulative		
1	0.297	0.297		
2	0.158	0.456		
3	0.113	0.569		
Increment and cumulative R-squared were adjusted for any lack of orthogonality of axes.				
Axis pair	r	Orthogonality,% = 100(1-r^2)		
1 vs 2	0.000	100.0		
1 vs 3	0.000	100.0		
2 vs 3	0.000	100.0		
Number of entities = 36				
Number of entity pairs used in correlation = 630				
Distance measure for ORIGINAL distance: Sorensen (Bray-Curtis)				

Area_NMS_Oct17-correlation with 2nd matrix									
Pearson and Kendall Correlations with Ordination Axes N= 36									
	Axis:	1			2			3	
	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
Bare	-0.102	0.01	-0.104	0.016	0	-0.062	0.214	0.046	0.097
Shrub	0.45	0.202	0.391	0.499	0.249	0.099	0.062	0.004	0.16
Tree	0.08	0.006	-0.168	0.494	0.244	0.342	0.241	0.058	0.1
Herb	0.739	0.546	0.833	0.337	0.114	0.07	0.004	0	0.051

Area_NMS_Oct17-correlation with the main matrix									
Pearson and Kendall Correlations with Ordination Axes N= 36									
	Axis:	1			2			3	
	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
SH1,2,3	0.45	0.202	0.391	0.499	0.249	0.099	0.062	0.004	0.16
Tree1&2	0.08	0.006	-0.168	0.494	0.244	0.342	0.241	0.058	0.1
H1	0.266	0.071	0.404	0.64	0.41	0.513	0.012	0	0.142
H2	0.09	0.008	-0.121	-0.294	0.086	-0.272	0.4	0.16	0.359
H3	0.292	0.085	0.127	-0.451	0.203	-0.482	0.57	0.325	0.544
H4	0.496	0.246	0.587	-0.028	0.001	-0.169	-0.534	0.285	-0.361
H5	0.072	0.005	-0.016	0.112	0.013	0.063	0.448	0.2	0.371
H6	0.184	0.034	0.169	-0.15	0.023	-0.163	0.055	0.003	0.037
H9	0.014	0	0.008	-0.38	0.145	-0.308	0.019	0	0.024
H10	-0.034	0.001	-0.053	0.15	0.023	0.158	0.339	0.115	0.273
H11	0.294	0.086	0.356	-0.21	0.044	-0.128	-0.158	0.025	-0.273
H12	-0.132	0.017	-0.128	-0.003	0	-0.007	-0.097	0.01	-0.101
Hweed	0.389	0.151	0.22	0.048	0.002	0.038	-0.014	0	0.053
Correlations with Ordination axes for each plant community in darker green as the main association and lighter									
green a secondary association slightly weaker									

Mantel test for association between two distance matrices

Bare ground testing just using the two Bare ground classes B1 and B2

********* Mantel test for association between two distance matrices *********
DATA MATRICES

Main matrix:
36 SmplUnit (rows)
13 Response (columns)
Distance matrix calculated from the main matrix.
Second matrix:
36 SmplUnit (rows)
2 Response (columns)
Distance matrix calculated from second matrix.

Method chosen is Mantel`s asymptotic approximation.
Algorithm based on: Douglas, M. E. & J. A. Endler. 1982.
Journal of Theoretical Ecology 99:777-795.
Original source: Mantel, N. 1967. Cancer Research 27:209-220.
Distance measure for second matrix = Sorensen (Bray-Curtis)
TEST STATISTIC: t-distribution with infinite degrees of freedom
using an asymptotic approximation of Mantel (1967).
If t < 0, then a negative association is indicated.

If t > 0, then a positive association is indicated.	
MANTEL TEST RESULTS: Mantel`s asymptotic approximation method	
--	
0.160105 = r = Standardized Mantel statistic	
0.251808E+03 = Observed Z (sum of cross products)	
0.247526E+03 = Expected Z	
0.138770E+01 = Variance of Z	
0.117801E+01 = Standard error of Z	
0.363519E+01 = t	
Ho: no relationship between matrices	
0.000292 = p (type I error)	
--	
H_{01} - there has been a significant increase in bare ground since 2009 in the -10 m drawdown zone	
Mantel test can be used to evaluate the association between paired matrices. My case veg community area (main matrix) and bare ground (2nd matrix).	
	P = 0.0003

Vegetation communities testing

********* Mantel test for association between two distance matrices *********
Distance measure for first matrix = Sorensen (Bray-Curtis)
Distance measure for second matrix = Sorensen (Bray-Curtis)
TEST STATISTIC: t-distribution with infinite degrees of freedom
using an asymptotic approximation of Mantel (1967).
If t < 0, then a negative association is indicated.
If t > 0, then a positive association is indicated.
MANTEL TEST RESULTS: Mantel`s asymptotic approximation method
----
0.363016 = r = Standardized Mantel statistic
0.256301E+03 = Observed Z (sum of cross products)
0.248154E+03 = Expected Z
0.930923E+00 = Variance of Z
0.964844E+00 = Standard error of Z
0.844345E+01 = t
Ho: no relationship between matrices
0.000000 = p (type I error)

Mantel test - resulting p-value evaluates the hypothesis of no relationship between two matrices.
tests for association, a high observed test statistic indicates high spatial autocorrelation between the two distance matrices, but it does not say if 1 dataset responds to the other or if both respond to a third factor.
H_{01} - there has been a significant change in community species since 2009 in the -10 m drawdown zone
P < 0.000

Testing at the quadrat level – Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
S1_Tot_09	49	0	35.000	25.000	55.000
S1_Tot_12	49	0	2.800	0.300	22.650
S1_Tot_15	49	0	30.400	17.750	41.450
S1_Tot_18	49	0	17.600	6.300	37.550
S2_Tot_09	84	0	23.750	10.000	70.000
S2_Tot_12	84	0	7.425	2.500	24.375
S2_Tot_15	84	0	10.000	2.700	22.700
S2_Tot_18	84	0	3.950	2.500	20.150
S3_Tot_09	13	0	70.000	20.200	83.750
S3_Tot_12	32	0	20.000	0.1000	57.500
S3_Tot_15	32	0	17.750	5.200	33.775
S3_Tot_18	32	0	17.700	3.350	40.075
S4_Tot_09	28	0	70.000	57.500	87.500
S4_Tot_12	28	0	28.800	15.000	77.575
S4_Tot_15	28	0	7.700	5.025	27.500
S4_Tot_18	28	0	17.550	2.800	35.675
S5_Tot_09	18	0	67.500	50.000	75.000
S5_Tot_12	29	0	35.000	22.500	57.550
S5_Tot_15	29	0	37.500	20.000	46.350
S5_Tot_18	29	0	15.200	2.600	28.800
S6_Tot_09	23	0	0.000	0.000	2.500
S6_Tot_12	38	0	0.000	0.000	0.000
S6_Tot_15	38	0	0.000	0.000	0.000
S6_Tot_18	38	0	0.000	0.000	0.000
S7_Tot_09	46	0	7.500	0.000	20.625
S7_Tot_12	46	0	0.000	0.000	0.1000
S7_Tot_15	46	0	0.000	0.000	5.000
S7_Tot_18	46	0	0.000	0.000	0.1000
S9_Tot_09	90	0	35.000	22.500	62.500
S9_Tot_12	90	0	2.500	0.000	22.500
S9_Tot_15	90	0	3.850	0.000	17.500
S9_Tot_18	90	0	0.1000	0.000	2.700
S10_Tot_09	73	0	35.000	17.600	52.550
S10_Tot_12	73	0	0.200	0.000	30.000
S10_Tot_15	73	0	5.000	0.000	17.500
S10_Tot_18	73	0	0.1000	0.000	2.600
S11_Tot_09	42	0	15.000	7.500	50.000
S11_Tot_12	42	0	0.300	0.200	17.600
S11_Tot_15	42	0	0.0500	0.000	17.500
S11_Tot_18	42	0	0.000	0.000	15.000
S12_Tot_09	45	0	17.500	7.600	40.000
S12_Tot_12	45	0	2.700	0.1000	15.000
S12_Tot_15	45	0	0.000	0.000	2.500
S12_Tot_18	45	0	0.1000	0.000	2.500
S13_Tot_09	52	0	87.500	62.525	100.000
S13_Tot_12	52	0	62.500	15.000	85.000
S13_Tot_15	52	0	56.250	20.100	71.250
S13_Tot_18	52	0	62.550	30.625	96.250

H = 1089.698 with 47 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

Testing at the quadrat level – Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
Tot% H_09	608	45	35.000	15.000	57.500
Tot%H_12	608	0	2.800	0.000	30.000
Tot%H_15	608	0	5.350	0.000	22.500
Tot%H_18	608	0	2.500	0.000	17.500

H = 327.504 with 3 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method):

Comparison	Diff of Ranks	Q	P<0.05
Tot% H_09 vs Tot%H_18	677.248	16.801	Yes
Tot% H_09 vs Tot%H_12	545.955	13.544	Yes
Tot% H_09 vs Tot%H_15	512.041	12.702	Yes
Tot%H_15 vs Tot%H_18	165.207	4.179	Yes
Tot%H_15 vs Tot%H_12	33.914	0.858	No
Tot%H_12 vs Tot%H_18	131.294	3.321	Yes

Note: The multiple comparisons on ranks do not include an adjustment for ties.

Kruskal-Wallis One Way Analysis of Variance on Ranks

Data source: Mean veg-2009-2018.JNB

Group	N	Missing	Median	25%	75%
Tot%S_09	608	45	0.000	0.000	0.000
Tot%S_12	608	0	0.000	0.000	0.000
Tot%S_15	608	0	0.000	0.000	0.000
Tot%S_18	608	0	0.000	0.000	0.000

H = 5.508 with 3 degrees of freedom. (P = 0.138)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.138)

Kruskal-Wallis One Way Analysis of Variance on Ranks

Data source: Mean veg-2009-2018.JNB

Group	N	Missing	Median	25%	75%
Tot%T_09	608	45	0.000	0.000	0.000
Tot%T_12	608	0	0.000	0.000	0.000
Tot%T_15	608	0	0.000	0.000	0.000
Tot%T_18	608	0	0.000	0.000	0.000

H = 13.335 with 3 degrees of freedom. (P = 0.004)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.004)

SPSS MANOVA Tables

SPSS MANOVA output for the best-fit single environmental factor, Location.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	LogCover	359[a]	11	32.7	81.1	.000
	SqrtRichness	616[b]	11	56.0	131	.000
Intercept	LogCover	1789	1	1789	4444	.000
	SqrtRichness	2633	1	2633	6140	.000
Location	LogCover	359	11	32.7	81.2	.000
	SqrtRichness	616	11	56.0	131	.000
Error	LogCover	974	2420	0.402		
	SqrtRichness	1038	2420	0.429		
Total	LogCover	3333	2432			
	SqrtRichness	4464	2432			
Corrected Total	LogCover	1333	2431			
	SqrtRichness	1654	2431			

a. R Squared = .270 (Adjusted R Squared = .266)
b. R Squared = .372 (Adjusted R Squared = .370)

SPSS MANOVA output for the best-fit two factor model for Cover, which combined Year and Location.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	LogCover	565[a]	43	13.1	40.8	.000
	SqrtRichness	691[b]	43	16.1	39.9	.000
Intercept	LogCover	1753	1	1753	5446	.000
	SqrtRichness	2616	1	2616	6490	.000
Year	LogCover	56.7	3	18.9	58.7	.000
	SqrtRichness	17.8	3	5.93	14.7	.000
Location	LogCover	357	10	35.7	111	.000
	SqrtRichness	614	10	61.4	152	.000
Year * Location	LogCover	87.0	30	2.90	9.01	.000
	SqrtRichness	55.3	30	1.85	4.58	.000
Error	LogCover	769	2388	.322		
	SqrtRichness	963	2388	.403		
Total	LogCover	3333	2432			
	SqrtRichness	4464	2432			
Corrected Total	LogCover	1333	2431			
	SqrtRichness	1654	2431			

a. R Squared = .423 (Adjusted R Squared = .413)
b. R Squared = .418 (Adjusted R Squared = .407)

SPSS MANOVA output for the best-fit two factor model for Richness, which combined Location and Substrate.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	LogCover	518[a]	142	3.65	10.5	0.00
	SqrtRichness	816[b]	142	5.75	16.4	0.00
Intercept	LogCover	519	1	519	1498	0.00
	SqrtRichness	823	1	823	2354	0.00
Location	LogCover	130	11	11.8	34.0	0.00
	SqrtRichness	316	11	28.7	82.2	0.00
SubstrateClass	LogCover	11.0	16	.690	1.99	0.011
	SqrtRichness	5.95	16	.372	1.06	0.385
Location * Substrate	LogCover	129	115	1.12	3.22	0.00
	SqrtRichness	152	115	1.32	3.78	0.00
Error	LogCover	778	2244	.347		
	SqrtRichness	785	2244	.350		
Total	LogCover	3333	2387			
	SqrtRichness	4464	2387			
Corrected Total	LogCover	1296	2386			
	SqrtRichness	1601	2386			

a. R Squared = .400 (Adjusted R Squared = .362)
b. R Squared = .510 (Adjusted R Squared = .479)

SPSS MANOVA output for the best-fit three factor model, which combined Year, Location and Substrate.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	LogCover	781[a]	365	2.14	8.41	.000
	SqrtRichness	967[b]	365	2.65	8.44	.000
Intercept	LogCover	599	1	599	2351	.000
	SqrtRichness	907	1	907	2892	.000
Year	LogCover	39.1	3	13.0	51.2	.000
	SqrtRichness	6.40	3	2.13	6.80	.000
Location	LogCover	120	11	10.9	42.9	.000
	SqrtRichness	292	11	26.6	84.7	.000
SubstrateClass	LogCover	9.84	16	0.615	2.42	.001
	SqrtRichness	5.68	16	0.355	1.13	.318
Year * Location	LogCover	26.9	33	0.814	3.20	.000
	SqrtRichness	25.6	33	0.776	2.48	.000
Year * Substrate	LogCover	22.2	46	0.482	1.89	.000
	SqrtRichness	16.0	46	0.347	1.11	.288
Location * Substrate	LogCover	61.1	114	0.536	2.10	.000
	SqrtRichness	98.5	114	0.864	2.76	.000
Year * Location * Substrate	LogCover	53.7	141	0.381	1.50	.000
	SqrtRichness	81.8	141	0.580	1.85	.000
Error	LogCover	515	2021	0.255		
	SqrtRichness	634	2021	0.314		
Total	LogCover	3333	2387			
	SqrtRichness	4464	2387			
Corrected Total	LogCover	1296	2386			
	SqrtRichness	1601	2386			

a. R Squared = .603 (Adjusted R Squared = .531)
b. R Squared = .604 (Adjusted R Squared = .532)

SPSS MANOVA output for a near best-fit three factor model, which combined Location, Exposure time and Substrate.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	LogCover	813[a]	677	1.20	4.25	.000
	SqrtRichness	1074[b]	677	1.59	5.15	.000
Intercept	LogCover	440	1	440	1556	.000
	SqrtRichness	710	1	710	2303	.000
Location	LogCover	72.8	11	6.62	23.4	.000
	SqrtRichness	215	11	19.5	63.3	.000
ExposureClass	LogCover	17.0	11	1.54	5.47	.000
	SqrtRichness	2.53	11	.230	.746	.695
SubstrateClass	LogCover	9.16	16	.572	2.03	.009
	SqrtRichness	7.60	16	.475	1.54	.077
Location * Exposure	LogCover	63.4	111	.571	2.02	.000
	SqrtRichness	68.0	111	.612	1.99	.000
Location * Substrate	LogCover	60.3	113	.534	1.89	.000
	SqrtRichness	95.2	113	.842	2.73	.000
Exposure* Substrate	LogCover	44.1	145	.304	1.08	.259
	SqrtRichness	49.2	145	.339	1.10	.205
Location * Exposure * Substrate	LogCover	106	264	.402	1.43	.000
	SqrtRichness	108	264	.411	1.33	.001
Error	LogCover	483	1709	.282		
	SqrtRichness	527	1709	.308		
Total	LogCover	3333	2387			
	SqrtRichness	4464	2387			
Corrected Total	LogCover	1296	2386			
	SqrtRichness	1601	2386			

a. R Squared = .628 (Adjusted R Squared = .480)
b. R Squared = .671 (Adjusted R Squared = .541)

Appendix 5: Photo Documentation

Date: June 7, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir		**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin		
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S1 T1	0	0	DSCN_5835	Herb Plot
	1		DSCN_5836	Looking at POC
	1		DSCN_5837	Looking down line
	1		DSCN_5838	Up reservoir
	1		DSCN_5839	Down reservoir
	86.6	-2	DSCN_5840	Herb Plot
	87.7		DSCN_5841	Looking at POC
	87.7		DSCN_5842	Looking down line
	87.7		DSCN_5843	Up reservoir
	87.7		DSCN_5844	Down reservoir
	140	-4	DSCN_5845	Herb Plot
	140		DSCN_5846	Looking at POC
	140		DSCN_5847	Looking down line
	140		DSCN_5848	Up reservoir
	140		DSCN_5849	Down reservoir
	177	-6	DSCN_5850	Herb Plot
	178		DSCN_5851	Looking at POC
	178		DSCN_5852	Looking down line
	178		DSCN_5853	Up reservoir
	178		DSCN_5854	Down reservoir
	212	-8	DSCN_5855	Herb Plot
	212		DSCN_5856	Looking at POC
	212		DSCN_5857	Looking down line
	212		DSCN_5858	Up reservoir
	212		DSCN_5859	Down reservoir
	278	-10	DSCN_5860	Herb Plot
	279		DSCN_5861	Looking at POC
	279		DSCN_5862	Looking down line
	279		DSCN_5863	Up reservoir
	279		DSCN_5864	Down reservoir
Upland	0	0	DSCN_5865	Looking at POC
	-15		DSCN_5866	Looking into the tree plot
	-15		DSCN_5867	Herb Plot
	-18		DSCN_5868	Looking at EOT
	-31	2	DSCN_5869	EOT

Date: June 7, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S1 Tr700	0	0	DSCN_5797	Herb Plot
New:Tr869	1		DSCN_5798	Looking at POC
	1		DSCN_5799	Looking down line
	1		DSCN_5800	Up reservoir
	1		DSCN_5801	Down reservoir
	17	-2	DSCN_5802	Herb Plot
	18		DSCN_5803	Looking at POC
	18		DSCN_5804	Looking down line
	18		DSCN_5805	Up reservoir
	18		DSCN_5806	Down reservoir
	30.4	-4	DSCN_5807	Herb Plot
	31.4		DSCN_5808	Looking at POC
	31.4		DSCN_5809	Looking down line
	31.4		DSCN_5810	Up reservoir
	31.4		DSCN_5811	Down reservoir
	60	-6	DSCN_5812	Herb Plot
	61		DSCN_5813	Looking at POC
	61		DSCN_5814	Looking down line
	61		DSCN_5815	Up reservoir
	61		DSCN_5816	Down reservoir
	96.5	-8	DSCN_5817	Herb Plot
	97.5		DSCN_5818	Looking at POC
	97.5		DSCN_5819	Looking down line
	97.5		DSCN_5820	Up reservoir
	97.5		DSCN_5821	Down reservoir
	133.6	-10	DSCN_5822	Herb Plot
	133.6		DSCN_5823	Looking at POC
	133.6		DSCN_5824	Looking down line
	133.6		DSCN_5825	Up reservoir
	133.6		DSCN_5826	Down reservoir
Upland	0	0	DSCN_5827	Looking down line
	-4		DSCN_5828	Looking down line
	-9		DSCN_5829	Looking down line
	-9		DSCN_5830	Up reservoir
	-19		DSCN_5831	Looking down line
	-19		DSCN_5832	Up reservoir
	-19		DSCN_5833	Down reservoir
	-24	2	DSCN_5834	EOT

Date: June 7, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S2 T701	5	0	DSCN_5909	Herb Plot
New: T884	5		DSCN_5910	Looking at POC
	5		DSCN_5911	Looking down line
	5		DSCN_5912	Up reservoir
	5		DSCN_5913	Down reservoir
	28	-2	DSCN_5914	Herb Plot
	29		DSCN_5915	Looking at POC
	29		DSCN_5916	Looking down line
	29		DSCN_5917	Up reservoir
	29		DSCN_5918	Down reservoir
	57	-4	DSCN_5919	Herb Plot
	58		DSCN_5920	Looking at POC
	58		DSCN_5921	looking down line
	58		DSCN_5922	up reservoir
	58		DSCN_5923	down reservoir
	162	-6	DSCN_5924	Herb Plot
	163		DSCN_5925	Looking at POC
	163		DSCN_5926	Looking down line
	163		DSCN_5927	Up reservoir
	163		DSCN_5928	Down reservoir
	237	-8	DSCN_5929	Herb Plot
	238		DSCN_5930	Looking at POC
	238		DSCN_5931	Looking down line
	238		DSCN_5932	Up reservoir
	238		DSCN_5933	Down reservoir
	287	-10	DSCN_5934	Herb Plot
	288		DSCN_5935	Looking at POC
	288		DSCN_5936	Looking down line
	288		DSCN_5937	Up reservoir
	288		DSCN_5938	Down reservoir
Upland	0	0	DSCN_5940	Looking at POC
	-6		DSCN_5941	Looking down line
	-6		DSCN_5942	Up reservoir
	-6		DSCN_5943	Down reservoir
	-15		DSCN_5944	Looking down line
	-15		DSCN_5945	Up reservoir
	-15		DSCN_5946	Down reservoir
	-18	2	DSCN_5947	EOT

Date: June 7, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S2 T702	0	0	DSCN_5978	Herb Plot
New: T885	1		DSCN_5979	Looking at POC
	1		DSCN_5980	Looking down line
	1		DSCN_5981	Up reservoir
	1		DSCN_5982	Down reservoir
	60	-1	DSCN_5973	Herb Plot
	61		DSCN_5974	Looking at POC
	61		DSCN_5975	Looking down line
	61		DSCN_5976	Up reservoir
	61		DSCN_5977	Down reservoir
	84	-2	DSCN_5968	Herb Plot
	85		DSCN_5969	Looking at POC
	85		DSCN_5970	Looking down line
	85		DSCN_5971	Up reservoir
	85		DSCN_5972	Down reservoir
	150	-4	DSCN_5963	Herb Plot
	151		DSCN_5964	Looking at POC
	151		DSCN_5965	Looking down line
	151		DSCN_5966	Up reservoir
	151		DSCN_5967	Down reservoir
	225	-6	DSCN_5958	Herb Plot
	226		DSCN_5959	Looking at POC
	226		DSCN_5960	Looking down line
	226		DSCN_5961	Up reservoir
	226		DSCN_5962	Down reservoir
	294	-8	DSCN_5953	Herb Plot
	295		DSCN_5954	Looking at POC
	295		DSCN_5955	Looking down line
	295		DSCN_5956	Up reservoir
	295		DSCN_5957	Down reservoir
	388	-10	DSCN_5948	Herb Plot
	389		DSCN_5949	Looking at POC
	389		DSCN_5950	Looking down line
	389		DSCN_5951	Up reservoir
	389		DSCN_5952	Down reservoir
Upland	0	0	DSCN_5983	Looking at POC
	0		DSCN_5984	Up line
	-21		DSCN_5985	Looking at POC
	-20	2	DSCN_5986	EOT

Date: June 7, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S2 T703	10	0	DSCN_5870	Herb Plot
New: T822	11		DSCN_5871	Looking at POC
	11		DSCN_5872	Looking down line
	11		DSCN_5873	Up reservoir
	11		DSCN_5874	Down reservoir
	29	-2	DSCN_5875	Herb Plot
	30		DSCN_5876	Looking at POC
	30		DSCN_5877	Looking down line
	30		DSCN_5878	Up reservoir
	30		DSCN_5879	Down reservoir
	150	-4	DSCN_5880	Herb Plot
	151		DSCN_5881	Looking at POC
	151		DSCN_5882	Looking down line
	151		DSCN_5883	Up reservoir
	151		DSCN_5884	Down reservoir
	246	-6	DSCN_5885	Herb Plot
	247		DSCN_5886	Looking at POC
	247		DSCN_5887	Looking down line
	247		DSCN_5888	Up reservoir
	247		DSCN_5889	Down reservoir
	282	-8	DSCN_5890	Herb plot
	283		DSCN_5891	Looking at POC
	283		DSCN_5892	Looking down line
	283		DSCN_5893	Up reservoir
	283		DSCN_5894	Down reservoir
	360	-10	DSCN_5895	H Plot
	361		DSCN_5896	Looking at POC
	361		DSCN_5897	Looking down line
	361		DSCN_5898	Up reservoir
	361		DSCN_5899	Down reservoir
Upland	0	0	DSCN_5900	Herb Plot
	0		DSCN_5901	Looking at POC
	0		DSCN_5902	Looking at POC - ground level
	-5		DSCN_5903	Up line
	-5		DSCN_5904	Down line
	-19		DSCN_5906	Down line
	-24	2	DSCN_5907	Up line
	-24		DSCN_5908	EOT

Date: June 6/7, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S3_Tr704	0	0	DSCN_6023	Herb Plot
	1		DSCN_6024	Looking at POC
	1		DSCN_6025	Looking down line
	1		DSCN_6026	Up reservoir
	1		DSCN_6027	Down reservoir
	10	-2	DSCN_6028	Herb plot
	11		DSCN_6029	Looking at POC
	11		DSCN_6030	Looking down line
	11		DSCN_6031	Up reservoir
	11		DSCN_6032	Down reservoir
	16	-4	DSCN_6033	Herb plot
	17		DSCN_6034	Looking at POC
	17		DSCN_6035	Looking down line
	17		DSCN_6036	Up reservoir
	17		DSCN_6037	Down reservoir
	31	-6	DSCN_6038	Herb Plot
	32		DSCN_6039	Looking at POC
	32		DSCN_6040	Looking down line
	32		DSCN_6041	Up reservoir
	32		DSCN_6042	Down reservoir
	43	-8	DSCN_6043	Herb Plot
	44		DSCN_6044	Looking at POC
	44		DSCN_6045	Looking down line
	44		DSCN_6046	Up reservoir
	44		DSCN_6047	Down reservoir
	64	-10	DSCN_6048	Herb Plot
	65		DSCN_6049	Looking at POC
	65		DSCN_6050	Looking down line
	65		DSCN_6051	Up reservoir
	65		DSCN_6052	Down reservoir
Upland	-1	0	DSCN_2610	Looking up line at EOT
	-5		DSCN_2611	Up reservoir
	-5		DSCN_2612	Down reservoir
	-25	2	DSCN_2613	EOT

Date: June 6/7, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S3Tr812	7	0	DSCN_5988	Herb Plot
	8		DSCN_5989	Looking at POC
	8		DSCN_5990	Looking down line
	8		DSCN_5991	Up reservoir
	8		DSCN_5992	Down reservoir
	17	-2	DSCN_5993	Herb Plot
	18		DSCN_5994	Looking at POC
	18		DSCN_5995	Looking down line
	18		DSCN_5996	Up reservoir
	18		DSCN_5997	Down reservoir
	23	-4	DSCN_5998	Herb Plot
	23		DSCN_5999	Looking at POC
	23		DSCN_6000	Looking down line
	23		DSCN_6001	Up reservoir
	23		DSCN_6002	Down reservoir
	29.4	-6	DSCN_6003	Herb Plot
	30.4		DSCN_6004	Looking at POC
	30.4		DSCN_6005	Looking down line
	30.4		DSCN_6006	Up reservoir
	30.4		DSCN_6007	Down reservoir
	36.3	-8	DSCN_6008	Herb Plot
	37.3		DSCN_6009	Looking at POC
	37.3		DSCN_6010	Looking down line
	37.3		DSCN_6011	Up reservoir
	37.3		DSCN_6012	Down reservoir
	47	-10	DSCN_6013	Herb Plot
	48		DSCN_6014	Looking at POC
	48		DSCN_6015	Looking down line
	48		DSCN_6016	Up reservoir
	48		DSCN_6017	Down reservoir
Upland	-1	0	DSCN_6018	Up line
	-1		DSCN_6019	Down line
	-5		DSCN_6020	Up line
	-5		DSCN_6021	Down line
	-6	2	DSCN_6022	EOT

Date: June 6, 2018	**Project Leader:** Mary Louise Polzin			
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S4 705	0	0	DSCN_5735	Herb Plot
	1		DSCN_5736	Looking at POC
	1		DSCN_5737	Looking down line
	1		DSCN_5738	Up reservoir
	1		DSCN_5739	Down reservoir
	13	-2	DSCN_5740	Herb Plot
	14		DSCN_5741	Looking at POC
	14		DSCN_5742	Looking down line
	14		DSCN_5743	Up reservoir
	14		DSCN_5744	Down reservoir
	29.5	-4	DSCN_5745	Herb Plot
	30.5		DSCN_5746	Looking at POC
	30.5		DSCN_5747	Looking down line
	30.5		DSCN_5748	Up reservoir
	30.5		DSCN_5749	Down reservoir
	49.5	-6	DSCN_5750	Herb Plot
	50.5		DSCN_5751	Looking at POC
	50.5		DSCN_5752	Looking down line
	50.5		DSCN_5753	Up reservoir
	50.5		DSCN_5754	Down reservoir
	61.5	-8	DSCN_5755	Herb Plot
	62.5		DSCN_5756	Looking at POC
	62.5		DSCN_5757	Looking down line
	62.5		DSCN_5758	Up reservoir
	62.5		DSCN_5759	Down reservoir
	73.5	-10	DSCN_5760	Herb Plot
	74.5		DSCN_5761	Looking at POC
	74.5		DSCN_5762	Looking down line
	74.5		DSCN_5763	Up reservoir
	74.5		DSCN_5764	Down reservoir
Upland	-4	0	DSCN_5727	Down line
	-4		DSCN_5728	Up line
	-4		DSCN_5729	Up reservoir
	-4		DSCN_5730	Down reservoir
	-7		DSCN_5731	Down line
	-7		DSCN_5732	Up line
	-12	2	DSCN_5734	EOT

Date: June 6, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S4 706	1	0	DSCN_5766	Herb Plot
	2		DSCN_5767	Looking at POC
	2		DSCN_5768	Looking down line
	2		DSCN_5769	Up reservoir
	2		DSCN_5770	Down reservoir
	7	-2	DSCN_5771	Herb Plot
	8		DSCN_5772	Looking at POC
	8		DSCN_5773	Looking down line
	8		DSCN_5774	Up reservoir
	8		DSCN_5775	Down reservoir
	21	-4	DSCN_5776	Herb Plot
	22		DSCN_5777	Looking at POC
	22		DSCN_5778	Looking down line
	22		DSCN_5779	Up reservoir
	22		DSCN_5780	Down reservoir
	36	-6	DSCN_5781	Herb Plot
	37		DSCN_5782	Looking at POC
	37		DSCN_5783	Looking down line
	37		DSCN_5784	Up reservoir
	37		DSCN_5785	Down reservoir
	50	-8	DSCN_5786	Herb Plot
	51		DSCN_5787	Looking at POC
	51		DSCN_5789	Looking down line
	51		DSCN_5790	Up reservoir
	51		DSCN_5791	Down reservoir
	54	-10	DSCN_5792	Herb Plot
	55		DSCN_5793	Looking at POC
	55		DSCN_5794	Looking down line
	55		DSCN_5795	Up reservoir
	55		DSCN_5796	Down reservoir
Upland	4	-	DSCN_5765	Standing at 4m mark looking up into upland; now owned, human disturbed.

Date: June 8, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S5_Tr 707	0.0	0	DSCN_6059	Herb Plot
	1.0		DSCN_6060	Looking at POC
	1.0		DSCN_6061	Looking down line
	1.0		DSCN_6062	Up reservoir
	1.0		DSCN_6063	Down reservoir
	37.0	-2	DSCN_6064	Herb Plot
	38.0		DSCN_6065	Looking at POC
	38.0		DSCN_6066	Looking down line
	38.0		DSCN_6067	Up reservoir
	38.0		DSCN_6068	Down reservoir
	60.0	-4	DSCN_6069	Herb Plot
	61.0		DSCN_6070	Looking at POC
	61.0		DSCN_6071	Looking down line
	61.0		DSCN_6072	Up reservoir
	61.0		DSCN_6073	Down reservoir
	83.0	-6	DSCN_6074	Herb Plot
	84.0		DSCN_6075	Looking at POC
	84.0		DSCN_6076	Looking down line
	84.0		DSCN_6077	Up reservoir
	84.0		DSCN_6078	Down reservoir
	105.0	-8	DSCN_6079	Herb Plot
	106.0		DSCN_6080	Looking at POC
	106.0		DSCN_6081	Looking down line
	106.0		DSCN_6082	Up reservoir
	106.0		DSCN_6083	Down reservoir
	128.0	-10	DSCN_6084	Herb Plot
	129.0		DSCN_6085	Looking at POC
	129.0		DSCN_6086	Looking down line
	129.0		DSCN_6087	Up reservoir
	129.0		DSCN_6088	Down reservoir
Upland	-1.0	0	DSCN_6089	Down line
	-5.0		DSCN_6091	Down reservoir
	-6.0		DSCN_6093	Up reservoir
	-12.0		DSCN_6094	Up line
	-12.0	2	DSCN_6095	EOT

Date: June 8, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S5_Tr 813	4.0	0	DSCN_6096	Herb Plot
	5.0		DSCN_6097	Looking at POC
	5.0		DSCN_6098	Looking down line
	5.0		DSCN_6099	Up reservoir
	5.0		DSCN_6100	Down reservoir
	23.4	-2	DSCN_6101	Herb Plot
	24.4		DSCN_6102	Looking at POC
	24.4		DSCN_6103	Looking down line
	24.4		DSCN_6104	Up reservoir
	24.4		DSCN_6105	Down reservoir
	35.6	-4	DSCN_6106	Herb Plot
	36.6		DSCN_6107	Looking at POC
	36.6		DSCN_6108	Looking down line
	36.6		DSCN_6109	Up reservoir
	36.6		DSCN_6110	Down reservoir
	47.0	-6	DSCN_6111	Herb Plot
	48.0		DSCN_6112	Looking at POC
	48.0		DSCN_6113	Looking down line
	48.0		DSCN_6114	Up reservoir
	48.0		DSCN_6115	Down reservoir
	59.7	-8	DSCN_6116	Herb Plot
	60.7		DSCN_6117	Looking at POC
	60.7		DSCN_6118	Looking down line
	60.7		DSCN_6119	Up reservoir
	60.7		DSCN_6120	Down reservoir
	71.4	-10	DSCN_6121	Herb Plot
	72.4		DSCN_6122	Looking at POC
	72.4		DSCN_6123	Looking down line
	72.4		DSCN_6124	Up reservoir
	72.4		DSCN_6125	Down reservoir
Upland	-1.0	0	DSCN_6126	Down line
	-5.0		DSCN_6127	Down reservoir
	-6.0		DSCN_6128	Up reservoir
	-12.0		DSCN_6129	Up line
	-12.0	2	DSCN_6130	EOT

Date: June 10, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S6_Tr 708	7	0	DSCN_6790	Herb Plot
	8		DSCN_6791	Looking at POC
	8		DSCN_6792	Looking down line
	8		DSCN_6793	Up reservoir
	8		DSCN_6794	Down reservoir
	13	-2	DSCN_6795	Herb Plot
	14		DSCN_6796	Looking at POC
	14		DSCN_6797	Looking down line
	14		DSCN_6798	Up reservoir
	14		DSCN_6799	Down reservoir
	26	-4	DSCN_6800	Herb Plot
	27		DSCN_6801	Looking at POC
	27		DSCN_6802	Looking down line
	27		DSCN_6803	Up reservoir
	27		DSCN_6804	Down reservoir
	37	-6	DSCN_6805	Herb Plot
	38		DSCN_6806	Looking at POC
	38		DSCN_6807	Looking down line
	38		DSCN_6808	Up reservoir
	38		DSCN_6809	Down reservoir
	48	-8	DSCN_6810	Herb Plot
	49		DSCN_6811	Looking at POC
	49		DSCN_6812	Looking down line
	49		DSCN_6813	Up reservoir
	49		DSCN_6814	Down reservoir
	55	-10	DSCN_6815	Herb Plot
	56		DSCN_6816	Looking at POC
	56		DSCN_6817	Looking down line
	56		DSCN_6818	Up reservoir
	56		DSCN_6819	Down reservoir
Upland	-12	0	DSCN_6785	Up line
	-12		DSCN_6786	Down line
	-12		DSCN_6787	Down reservoir
	-12		DSCN_6788	Up reservoir
	-15		DSCN_6789	EOT

Date: June 10, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir		**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin		
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S6_Tr814	1	0	DSCN_6829	Herb Plot
	1		DSCN_6830	Looking at POC
	1		DSCN_6831	Looking down line
	1		DSCN_6832	Up reservoir
	1		DSCN_6833	Down reservoir
	7.7	-2	DSCN_6834	Herb Plot
	8.7		DSCN_6835	Looking at POC
	8.7		DSCN_6836	Looking down line
	8.7		DSCN_6837	Up reservoir
	8.7		DSCN_6838	Down reservoir
	12.4	-4	DSCN_6839	Herb Plot
	13.4		DSCN_6840	Looking at POC
	13.4		DSCN_6841	Looking down line
	13.4		DSCN_6842	Up reservoir
	13.4		DSCN_6843	Down reservoir
	18.3	-6	DSCN_6844	Herb Plot
	19.3		DSCN_6845	Looking at POC
	19.3		DSCN_6846	Looking down line
	19.3		DSCN_6847	Up reservoir
	19.3		DSCN_6848	Down reservoir
	26	-8	DSCN_6849	Herb Plot
	27		DSCN_6850	Looking at POC
	27		DSCN_6851	Looking down line
	27		DSCN_6852	Up reservoir
	27		DSCN_6853	Down reservoir
	35.3	-10	DSCN_6854	Herb Plot
	36.3		DSCN_6855	Looking at POC
	36.3		DSCN_6858	Looking down line
	36.3		DSCN_6856	Up reservoir
	36.3		DSCN_6857	Down reservoir
Upland	0		DSCN_6820	Herb Plot
	0		DSCN_6822	Looking up line
	0		DSCN_6823	Up reservoir
	0		DSCN_6824	Down reservoir
	-1		DSCN_6821	Looking down line
	-11		DSCN_6827	Up reservoir

Date: June 8, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S7_Tr 2	0.0	0	DSCN_6131	Herb Plot
	1.0		DSCN_6132	Looking at POC
	1.0		DSCN_6133	Looking down line
	1.0		DSCN_6134	Up reservoir
	1.0		DSCN_6135	Down reservoir
	20.0	-2	DSCN_6136	Herb Plot
	21.0		DSCN_6137	Looking at POC
	21.0		DSCN_6138	Looking down line
	21.0		DSCN_6139	Up reservoir
	21.0		DSCN_6140	Down reservoir
	27.0	-4	DSCN_6141	Herb Plot
	28.0		DSCN_6142	Looking at POC
	28.0		DSCN_6143	Looking down line
	28.0		DSCN_6144	Up reservoir
	28.0		DSCN_6145	Down reservoir
	32.0	-6	DSCN_6146	Herb Plot
	33.0		DSCN_6147	Looking at POC
	33.0		DSCN_6148	Looking down line
	33.0		DSCN_6149	Up reservoir
	33.0		DSCN_6150	Down reservoir
	37.0	-8	DSCN_6151	Herb Plot
	38.0		DSCN_6152	Looking at POC
	38.0		DSCN_6153	Looking down line
	38.0		DSCN_6154	Up reservoir
	38.0		DSCN_6155	Down reservoir
	42.0	-10	DSCN_6156	Herb Plot
	43.0		DSCN_6157	Looking at POC
	43.0		DSCN_6158	Looking down line
	43.0		DSCN_6159	Up reservoir
	43.0		DSCN_6160	Down reservoir
Upland	0.0	0	DSCN_6161	Down line
	-4.0		DSCN_6162	Up reservoir
	-10.0		DSCN_6163	Down/Res side at line
	-12.0		DSCN_6164	Up/Res side at line
	-19.0		DSCN_6165	Down reservoir
	-24.0	2	DSCN_6166	EOT

Date: June 8, 2018	**Project Leader:** Mary Louise Polzin			
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S7_Tr3	0.0	0	DSCN_6167	Herb Plot
	1.0		DSCN_6168	Looking at POC
	1.0		DSCN_6169	Looking down line
	1.0		DSCN_6170	Up reservoir
	1.0		DSCN_6171	Down reservoir
	9.0	-2	DSCN_6172	Herb Plot
	10.0		DSCN_6173	Looking at POC
	10.0		DSCN_6174	Looking down line
	10.0		DSCN_6175	Up reservoir
	10.0		DSCN_6176	Down reservoir
	25.0	-4	DSCN_6177	Herb Plot
	26.0		DSCN_6178	Looking at POC
	26.0		DSCN_6179	Looking down line
	26.0		DSCN_6180	Up reservoir
	26.0		DSCN_6181	Down reservoir
	32.0	-6	DSCN_6182	Herb Plot
	33.0		DSCN_6183	Looking at POC
	33.0		DSCN_6184	Looking down line
	33.0		DSCN_6185	Up reservoir
	33.0		DSCN_6186	Down reservoir
	41.0	-8	DSCN_6187	Herb Plot
	42.0		DSCN_6188	Looking at POC
	42.0		DSCN_6189	Looking down line
	42.0		DSCN_6190	Up reservoir
	42.0		DSCN_6191	Down reservoir
	45.0	-10	DSCN_6192	Herb Plot
	46.0		DSCN_6193	Looking at POC
	46.0		DSCN_6194	Looking down line
	46.0		DSCN_6195	Up reservoir
	46.0		DSCN_6196	Down reservoir
Upland	-5.0	0	DSCN_6197	Down line
	-5.0		DSCN_6198	Tree plot area
	-7.0	2	DSCN_6199	Up line
	-7.0		DSCN_6200	Up line
	-7.0		DSCN_6201	EOT
	-12.0		DSCN_6202	Shrubs cleared at this mark

Date: June 9, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S9_Tr 709	1	0	DSCN_6578	Herb Plot
	2		DSCN_6579	Looking at POC
	2		DSCN_6580	Looking down line
	2		DSCN_6581	Up reservoir
	2		DSCN_6582	Down reservoir
	10		DSCN_6583	Herb Plot
	11		DSCN_6584	Looking at POC
	11		DSCN_6585	Looking down line
	11		DSCN_6586	Up reservoir
	11		DSCN_6587	Down reservoir
	17	-2	DSCN_6588	Herb Plot
	18		DSCN_6589	Looking at POC
	18		DSCN_6590	Looking down line
	18		DSCN_6591	Up reservoir
	18		DSCN_6592	Down reservoir
	34	-4	DSCN_6593	Herb Plot
	35		DSCN_6594	Looking at POC
	35		DSCN_6595	Looking down line
	35		DSCN_6596	Up reservoir
	35		DSCN_6597	Down reservoir
	55	-6	DSCN_6598	Herb Plot
	56		DSCN_6599	Looking at POC
	56		DSCN_6600	Looking down line
	56		DSCN_6601	Up reservoir
	56		DSCN_6602	Down reservoir
	77	-8	DSCN_6603	Herb Plot
	78		DSCN_6604	Looking at POC
	78		DSCN_6605	Looking down line
	78		DSCN_6606	Up reservoir
	78		DSCN_6607	Down reservoir
	105	-10	DSCN_6608	Herb Plot
	106		DSCN_6609	Looking at POC
	106		DSCN_6610	Looking down line
	106		DSCN_6611	Up reservoir
	106		DSCN_6612	Down reservoir
Upland	6	0	DSCN_6613	Up line
	-7		DSCN_6614	Down/Res side - line
	-7	2	DSCN_6615	EOT

Date: June 9, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S9_Tr 710	0	0	DSCN_6548	Herb Plot
	1		DSCN_6549	Looking at POC
	1		DSCN_6550	Looking down line
	1		DSCN_6551	Up reservoir
	1		DSCN_6552	Down reservoir
	13	-2	DSCN_6553	Herb Plot
	14		DSCN_6554	Looking at POC
	14		DSCN_6555	Looking down line
	14		DSCN_6556	Up reservoir
	14		DSCN_6557	Down reservoir
	34	-4	DSCN_6558	Herb Plot
	35		DSCN_6559	Looking at POC
	35		DSCN_6560	Looking down line
	35		DSCN_6561	Up reservoir
	35		DSCN_6562	Down reservoir
	50.2	-6	DSCN_6563	Herb Plot
	51.2		DSCN_6564	Looking at POC
	51.2		DSCN_6565	Looking down line
	51.2		DSCN_6566	Up reservoir
	51.2		DSCN_6567	Down reservoir
	81.4	-8	DSCN_6568	Herb Plot
	82.4		DSCN_6569	Looking at POC
	82.4		DSCN_6570	Looking down line
	82.4		DSCN_6571	Up reservoir
	82.4		DSCN_6572	Down reservoir
	107.5	-10	DSCN_6573	Herb Plot
	108.5		DSCN_6574	Looking at POC
	108.5		DSCN_6575	Looking down line
	108.5		DSCN_6576	Up reservoir
	108.5		DSCN_6577	Down reservoir
Uplands	0	0	DSCN_6542	Down line
	-2		DSCN_6543	Down line
	-8		DSCN_6544	Down reservoir
	-8		DSCN_6545	Up reservoir
	-10		DSCN_6546	Up line
	-13.5	2	DSCN_6547	EOT

Date: June 9, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S9_Tr 711	2	0	DSCN_6502	Herb Plot
	3		DSCN_6503	Looking at POC
	3		DSCN_6504	Looking down line
	3		DSCN_6505	Up reservoir
	3		DSCN_6506	Down reservoir
	17	-2	DSCN_6507	Herb Plot
	18		DSCN_6508	Looking at POC
	18		DSCN_6509	Looking down line
	18		DSCN_6510	Up reservoir
	18		DSCN_6511	Down reservoir
	44	-4	DSCN_6512	Herb Plot
	45		DSCN_6513	Looking at POC
	45		DSCN_6514	Looking down line
	45		DSCN_6515	Up reservoir
	45		DSCN_6516	Down reservoir
	70.2	-6	DSCN_6517	Herb Plot
	71.2		DSCN_6518	Looking at POC
	71.2		DSCN_6519	Looking down line
	71.2		DSCN_6520	Up reservoir
	71.2		DSCN_6521	Down reservoir
	115.5	-8	DSCN_6522	Herb Plot
	116.5		DSCN_6523	Looking at POC
	116.5		DSCN_6524	Looking down line
	116.5		DSCN_6525	Up reservoir
	116.5		DSCN_6526	Down reservoir
	151	-10	DSCN_6527	Herb Plot
	152		DSCN_6528	Looking at POC
	152		DSCN_6529	Looking down line
	152		DSCN_6530	Up reservoir
	152		DSCN_6531	Down reservoir
			DSCN_6541	Between 711 & 710 eroded; now horsetail
Upland	-8	0	DSCN_6535	Down line
	-8		DSCN_6536	Up line
	-8		DSCN_6538	Down reservoir
	-12		DSCN_6539	Up line
	-14	2	DSCN_6540	EOT

Date: June 9, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S9_Tr 712	1	0	DSCN_6460	H Plot
	2		DSCN_6461	Looking at POC
	2		DSCN_6462	Looking down line
	2		DSCN_6463	Up reservoir
	2		DSCN_6464	Down reservoir
	18	-2	DSCN_6465	H Plot
	19		DSCN_6466	Looking at POC
	19		DSCN_6467	Looking down line
	19		DSCN_6468	Up reservoir
	19		DSCN_6469	Down reservoir
	32	-4	DSCN_6470	H Plot
	39		DSCN_6471	Looking at POC
	39		DSCN_6472	Looking down line
	39		DSCN_6473	Up reservoir
	39		DSCN_6474	Down reservoir
	51		DSCN_6475	H Plot
	52		DSCN_6476	Looking at POC
	52		DSCN_6477	Looking down line
	52		DSCN_6478	Up reservoir
	52		DSCN_6479	Down reservoir
	70	-6	DSCN_6480	H Plot
	71		DSCN_6481	Looking at POC
	71		DSCN_6482	Looking down line
	71		DSCN_6483	Up reservoir
	71		DSCN_6484	Down reservoir
	125	-8	DSCN_6485	H Plot
	126		DSCN_6486	Looking at POC
	126		DSCN_6487	Looking down line
	126		DSCN_6488	Up reservoir
	126		DSCN_6489	Down reservoir
	168	-10	DSCN_6490	H Plot
	169		DSCN_6491	Looking at POC
	169		DSCN_6492	Looking down line
	169		DSCN_6493	Up reservoir
	169		DSCN_6494	Down reservoir
Upland	-1	0	DSCN_6496	Down line
	-4		DSCN_6497	Down line
	-4		DSCN_6498	Up line
	-8		DSCN_6499	Down line
	-8		DSCN_6500	Up line
	-13	2	DSCN_6501	EOT

Date: June 8, 2018	**Project Leader:** Mary Louise Polzin			
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S10_Tr 714	0.0	0	DSCN_6275	Herb Plot
	1.0		DSCN_6276	Looking at POC
	1.0		DSCN_6277	Looking down line
	1.0		DSCN_6278	Up reservoir
	1.0		DSCN_6279	Down reservoir
	15.0	-2	DSCN_6280	Herb Plot
	16.0		DSCN_6281	Looking at POC
	16.0		DSCN_6282	Looking down line
	16.0		DSCN_6283	Up reservoir
	16.0		DSCN_6284	Down reservoir
	35.6	-4	DSCN_6285	Herb Plot
	36.6		DSCN_6286	Looking at POC
	36.6		DSCN_6287	Looking down line
	36.6		DSCN_6288	Up reservoir
	36.6		DSCN_6289	Down reservoir
	52.5	-6	DSCN_6290	Herb Plot
	53.5		DSCN_6291	Looking at POC
	53.5		DSCN_6292	Looking down line
	53.5		DSCN_6293	Up reservoir
	53.5		DSCN_6294	Down reservoir
	68.8	-8	DSCN_6295	Herb Plot
	69.8		DSCN_6296	Looking at POC
	69.8		DSCN_6297	Looking down line
	69.8		DSCN_6298	Up reservoir
	69.8		DSCN_6299	Down reservoir
	83.7	-10	DSCN_6300	Herb Plot
	84.7		DSCN_6301	Looking at POC
	84.7		DSCN_6302	Looking down line
	84.7		DSCN_6303	Up reservoir
	84.7		DSCN_6304	Down reservoir
	46.0		DSCN_6309	Clumps of dead sedge
	46.0		DSCN_6310	Clumps of dead sedge
	46.0		DSCN_6311	Clumps of dead sedge
	46.0		DSCN_6312	Clumps of dead sedge
	46.0		DSCN_6313	Clumps of dead sedge
	46.0		DSCN_6314	Clumps of dead sedge
	46.0		DSCN_6315	Clumps of dead sedge
Upland	-2.0	0	DSCN_6305	Down line
	-8.0		DSCN_6306	Down line
	-8.0		DSCN_6307	Up line
	-11.0	2	DSCN_6308	EOT

Date: June 8, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S10_Tr713	1.0	0	DSCN_6240	Herb Plot
	2.0		DSCN_6241	Looking at POC
	2.0		DSCN_6242	Looking down line
	2.0		DSCN_6243	Up reservoir
	2.0		DSCN_6244	Down reservoir
	11.0	-2	DSCN_6245	Herb Plot
	12.0		DSCN_6246	Looking at POC
	12.0		DSCN_6247	Looking down line
	12.0		DSCN_6248	Up reservoir
	12.0		DSCN_6249	Down reservoir
	25.0	-4	DSCN_6250	Herb Plot
	26.0		DSCN_6251	Looking at POC
	26.0		DSCN_6252	Looking down line
	26.0		DSCN_6253	Up reservoir
	26.0		DSCN_6254	Down reservoir
	51.0	-6	DSCN_6255	Herb Plot
	52.0		DSCN_6256	Looking at POC
	52.0		DSCN_6257	Looking down line
	52.0		DSCN_6258	Up reservoir
	52.0		DSCN_6259	Down reservoir
	70.2	-8	DSCN_6260	Herb Plot
	71.2		DSCN_6261	Looking at POC
	71.2		DSCN_6262	Looking down line
	71.2		DSCN_6263	Up reservoir
	71.2		DSCN_6264	Down reservoir
	83.6	-10	DSCN_6265	Herb Plot
	84.6		DSCN_6266	Looking at POC
	84.6		DSCN_6267	Looking down line
	84.6		DSCN_6268	Up reservoir
	84.6		DSCN_6269	Down reservoir
Upland	-1.0	0	DSCN_6270	Down line
	-4.0		DSCN_6271	Up line
	-4.0		DSCN_6272	Down line
	-8.0		DSCN_6273	Up line
	-14.0	2	DSCN_6274	EOT

Date: June 8, 2018	**Project Leader:** Mary Louise Polzin			
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S10_Tr6	2.0	0	DSCN_6203	Herb Plot
	3.0		DSCN_6204	Looking at POC
	3.0		DSCN_6205	Looking down line
	3.0		DSCN_6206	Up reservoir
	3.0		DSCN_6207	Down reservoir
	17.0	-2	DSCN_6208	Herb Plot
	18.0		DSCN_6209	Looking at POC
	18.0		DSCN_6210	Looking down line
	18.0		DSCN_6211	Up reservoir
	18.0		DSCN_6212	Down reservoir
	44.0	-4	DSCN_6213	Herb Plot
	45.0		DSCN_6214	Looking at POC
	45.0		DSCN_6215	Looking down line
	45.0		DSCN_6216	Up reservoir
	45.0		DSCN_6217	Down reservoir
	70.0	-6	DSCN_6218	Herb Plot
	71.0		DSCN_6219	Looking at POC
	71.0		DSCN_6220	Looking down line
	71.0		DSCN_6221	Up reservoir
	71.0		DSCN_6222	Down reservoir
	100.0	-8	DSCN_6223	Herb Plot
	101.0		DSCN_6224	Looking at POC
	101.0		DSCN_6225	Looking down line
	101.0		DSCN_6226	Up reservoir
	101.0		DSCN_6227	Down reservoir
	150.0	-10	DSCN_6228	Herb Plot
	151.0		DSCN_6229	Looking at POC
	151.0		DSCN_6230	Looking down line
	151.0		DSCN_6231	Up reservoir
	151.0		DSCN_6232	Down reservoir
Upland	-1.0	0	DSCN_6233	Down line
	-1.0		DSCN_6234	Down reservoir
	-5.0		DSCN_6235	Down line
	-10.0		DSCN_6236	Down line
	-10.0		DSCN_6237	Up reservoir
	-10.0		DSCN_6238	Up line
	-24.0	2	DSCN_6239	EOT

Date: June 9, 2018	**Project Leader:** Mary Louise Polzin			
Location: Duncan Reservoir	**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin			
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S11_TR715	0	0	DSCN_6352	Herb Plot
	1		DSCN_6353	Looking at POC
	1		DSCN_6354	Looking down line
	1		DSCN_6355	Up reservoir
	1		DSCN_6356	Down reservoir
	13	-2	DSCN_6357	Herb Plot
	14		DSCN_6358	Looking at POC
	14		DSCN_6359	Looking down line
	14		DSCN_6360	Up reservoir
	14		DSCN_6361	Down reservoir
	26	-4	DSCN_6362	Herb Plot
	27		DSCN_6363	Looking at POC
	27		DSCN_6364	Looking down line
	27		DSCN_6365	Up reservoir
	27		DSCN_6366	Down reservoir
	38	-6	DSCN_6367	Herb Plot
	39		DSCN_6368	Looking at POC
	39		DSCN_6369	Looking down line
	39		DSCN_6370	Up reservoir
	39		DSCN_6371	Down reservoir
	58	-8	DSCN_6372	Herb Plot
	59		DSCN_6373	Looking at POC
	59		DSCN_6374	Looking down line
	59		DSCN_6376	Up reservoir
	59		DSCN_6377	Down reservoir
	72	-10	DSCN_6378	Herb Plot
	73		DSCN_6379	Looking at POC
	73		DSCN_6380	Looking down line
	73		DSCN_6381	Up reservoir
	73		DSCN_6382	Down reservoir
Upland	-2	0	DSCN_6384	Down line
	-2		DSCN_6385	Up line
	-8		DSCN_6386	Down line
	-8		DSCN_6387	Up line
	-7	2	DSCN_6388	Down reservoir

Date: June 9, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S11_TR716	7	0	DSCN_6316	Herb Plot driftwood
	8		DSCN_6317	Looking at POC
	8		DSCN_6318	Looking down line
	8		DSCN_6319	Up reservoir
	8		DSCN_6320	Down reservoir
	13	-2	DSCN_6321	Herb Plot
	14		DSCN_6322	Looking at POC
	14		DSCN_6323	Looking down line
	14		DSCN_6324	Up reservoir
	14		DSCN_6325	Down reservoir
	26	-4	DSCN_6326	Herb Plot
	27		DSCN_6327	Looking at POC
	27		DSCN_6328	Looking down line
	27		DSCN_6329	Up reservoir
	27		DSCN_6330	Down reservoir
	39	-6	DSCN_6331	Herb Plot
	40		DSCN_6332	Looking at POC
	40		DSCN_6333	Looking down line
	40		DSCN_6334	Up reservoir
	40		DSCN_6335	Down reservoir
	57	-8	DSCN_6336	Herb Plot
	58		DSCN_6337	Looking at POC
	58		DSCN_6338	Looking down line
	58		DSCN_6339	Up reservoir
	58		DSCN_6340	Down reservoir
	71	-10	DSCN_6341	Herb Plot
	72		DSCN_6342	Looking at POC
	72		DSCN_6343	Looking down line
	72		DSCN_6344	Up reservoir
	72		DSCN_6345	Down reservoir
Upland	-1	0	DSCN_6346	Down line
	-1		DSCN_6347	Up line
	-5		DSCN_6348	Down line
	-5		DSCN_6350	Up line
	-7	2	DSCN_6351	EOT

Date: June 9, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S12_TR718	0	0	DSCN_6425	Herb Plot
	1		DSCN_6426	Looking at POC
	1		DSCN_6427	Looking down line
	1		DSCN_6428	Up reservoir
	1		DSCN_6429	Down reservoir
	9	-2	DSCN_6430	Herb Plot
	10		DSCN_6431	Looking at POC
	10		DSCN_6432	Looking down line
	10		DSCN_6433	Up reservoir
	10		DSCN_6434	Down reservoir
	19	-4	DSCN_6435	Herb Plot
	20		DSCN_6436	Looking at POC
	20		DSCN_6437	Looking down line
	20		DSCN_6438	Up reservoir
	20		DSCN_6439	Down reservoir
	27	-6	DSCN_6440	Herb Plot
	28		DSCN_6441	Looking at POC
	28		DSCN_6442	Looking down line
	28		DSCN_6443	Up reservoir
	28		DSCN_6444	Down reservoir
	43	-8	DSCN_6445	Herb Plot
	44		DSCN_6446	Looking at POC
	44		DSCN_6447	Looking down line
	44		DSCN_6448	Up reservoir
	44		DSCN_6449	Down reservoir
	49	-10	DSCN_6450	Herb Plot
	50		DSCN_6451	Looking at POC
	50		DSCN_6452	Looking down line
	50		DSCN_6453	Up reservoir
	50		DSCN_6454	Down reservoir
Upland	-7	0	DSCN_6455	Down line-down/res side
	-7		DSCN_6456	Up line
	-7		DSCN_6457	Down line-up/res side
	-7		DSCN_6458	EOT
	-7		DSCN_6459	At EOT looking toward the new road

Date: June 9, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S12_TR5	0	0	DSCN_6389	Herb Plot
	1		DSCN_6390	Looking at POC
	1		DSCN_6391	Looking down line
	1		DSCN_6392	Up reservoir
	1		DSCN_6393	Down reservoir
	11	-2	DSCN_6394	Herb Plot
	12		DSCN_6395	Looking at POC
	12		DSCN_6396	Looking down line
	12		DSCN_6397	Up reservoir
	12		DSCN_6398	Down reservoir
	19	-4	DSCN_6399	Herb Plot
	20		DSCN_6400	Looking at POC
	20		DSCN_6401	Looking down line
	20		DSCN_6402	Up reservoir
	20		DSCN_6403	Down reservoir
	31	-6	DSCN_6404	Herb Plot
	32		DSCN_6405	Looking at POC
	32		DSCN_6406	Looking down line
	32		DSCN_6407	Up reservoir
	32		DSCN_6408	Down reservoir
	44	-8	DSCN_6409	Herb Plot
	45		DSCN_6410	Looking at POC
	45		DSCN_6411	Looking down line
	45		DSCN_6412	Up reservoir
	45		DSCN_6413	Down reservoir
	58	-10	DSCN_6414	Herb Plot
	59		DSCN_6415	Looking at POC
	59		DSCN_6416	Looking down line
	59		DSCN_6417	Up reservoir
	59		DSCN_6418	Down reservoir
Upland	-4	0	DSCN_6419	Down line
	-4		DSCN_6420	Up line
	-8		DSCN_6421	Down reservoir
	-8		DSCN_6422	Up reservoir
	-12	2	DSCN_6423	EOT
	-12		DSCN_6424	POC

Date: June 10, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S13_Tr717	0	0	DSCN_6618	Herb Plot
	1		DSCN_6619	Looking at POC
	1		DSCN_6620	Looking down line
	1		DSCN_6621	Up reservoir
	1		DSCN_6622	Down reservoir
	14		DSCN_6630	Herb Plot
	15		DSCN_6631	Looking at POC
	15		DSCN_6632	Looking down line
	15		DSCN_6633	Up reservoir
	15		DSCN_6634	Down reservoir
	31	-2	DSCN_6635	Herb Plot
	32		DSCN_6636	Looking at POC
	32		DSCN_6637	Looking down line
	32		DSCN_6638	Up reservoir
	32		DSCN_6639	Down reservoir
	40		DSCN_6640	Herb Plot
	41		DSCN_6641	Looking at POC
	41		DSCN_6642	Looking down line
	41		DSCN_6643	Up reservoir
	41		DSCN_6644	Down reservoir
	48	-3	DSCN_6645	Herb Plot
	49		DSCN_6646	Looking at POC
	49		DSCN_6647	Looking down line
	49		DSCN_6648	Up reservoir
	49		DSCN_6649	Down reservoir
	53		DSCN_6650	Herb Plot
	54		DSCN_6651	Looking at POC
	54		DSCN_6652	Looking down line
	54		DSCN_6653	Up reservoir
	54		DSCN_6654	Down reservoir
	100		DSCN_6655	Herb Plot
	101		DSCN_6656	Looking at POC
	101		DSCN_6657	Looking down line
	101		DSCN_6658	Up reservoir
	101		DSCN_6659	Down reservoir
Upland	-1	0	DSCN_6023	At POC - tree plot
	-1		DSCN_6024	Down reservoir side - tree plot
	-1		DSCN_6025	Up reservoir side - tree plot
	-1		DSCN_6026	Up reservoir
	-10		DSCN_6027	Down reservoir
	-10		DSCN_6028	Up reservoir
	-10		DSCN_6029	POC (taken above bushes)

Date: June 10, 2018	**Project Leader:** Mary Louise Polzin			
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S13_Tr4	0	0	DSCN_6667	Herb Plot
	1		DSCN_6668	Looking at POC
	1		DSCN_6669	Looking down line
	1		DSCN_6670	Up reservoir
	1		DSCN_6671	Down reservoir
	23	-1	DSCN_6672	Herb Plot
	24		DSCN_6673	Looking at POC
	24		DSCN_6674	Looking down line
	24		DSCN_6675	Up reservoir
	24		DSCN_6676	Down reservoir
	40		DSCN_6677	Herb Plot
	41		DSCN_6678	Looking at POC
	41		DSCN_6679	Looking down line
	41		DSCN_6680	Up reservoir
	41		DSCN_6681	Down reservoir
	46	-2	DSCN_6682	Herb Plot
	47		DSCN_6683	Looking at POC
	47		DSCN_6684	Looking down line
	47		DSCN_6685	Up reservoir
	47		DSCN_6686	Down reservoir
	65	-3	DSCN_6687	Herb Plot
	66		DSCN_6688	Looking at POC
	66		DSCN_6689	Looking down line
	66		DSCN_6690	Up reservoir
	66		DSCN_6691	Down reservoir
	99		DSCN_6692	Herb Plot
	100		DSCN_6693	Looking at POC
	100		DSCN_6694	Looking down line
	100		DSCN_6695	Up reservoir
	100		DSCN_6696	Down reservoir
Upland	-10	0	DSCN_6660	Up line
	-10		DSCN_6661	Down reservoir
	-10		DSCN_6662	Up reservoir
	-13		DSCN_6663	Down line
	-13		DSCN_6664	Down reservoir
	-13		DSCN_6665	Up line
	-13		DSCN_6666	POC

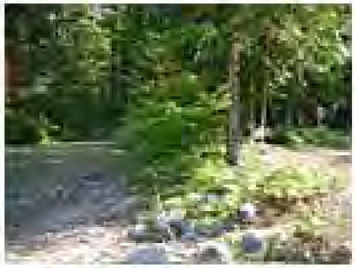
Date: June 10, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S13_Tr719	0	0	DSCN_6706	Herb Plot
	1		DSCN_6707	Looking at POC
	1		DSCN_6708	Looking down line
	1		DSCN_6709	Up reservoir
	1		DSCN_6710	Down reservoir
	35	-2	DSCN_6711	Herb Plot
	36		DSCN_6712	Looking at POC
	36		DSCN_6713	Looking down line
	36		DSCN_6714	Up reservoir
	36		DSCN_6715	Down reservoir
	54	-3	DSCN_6716	Herb Plot
	56		DSCN_6717	Looking at POC
	56		DSCN_6718	Looking down line
	56		DSCN_6719	Up reservoir
	56		DSCN_6720	Down reservoir
	70	-4	DSCN_6721	Herb Plot
	71		DSCN_6722	Looking at POC
	71		DSCN_6723	Looking down line
	71		DSCN_6724	Up reservoir
	71		DSCN_6725	Down reservoir
	82		DSCN_6726	Herb Plot
	83		DSCN_6727	Looking at POC
	83		DSCN_6728	Looking down line
	83		DSCN_6729	Up reservoir
	83		DSCN_6730	Down reservoir
	89		DSCN_6731	Herb Plot
	90		DSCN_6732	Looking at POC
	90		DSCN_6733	Looking down line
	90		DSCN_6734	Up reservoir
	90		DSCN_6735	Down reservoir
	100	-5	DSCN_6736	Herb Plot
	101		DSCN_6737	Looking at POC
	101		DSCN_6738	Looking down line
	101		DSCN_6739	Up reservoir
	101		DSCN_6740	Down reservoir
Upland	-5	0	DSCN_6697	Up line
	-5		DSCN_6698	Down line
	-5		DSCN_6699	Down reservoir
	-5		DSCN_6700	Up reservoir
	-20		DSCN_6701	Up line
	-20		DSCN_6702	Down line
	-20		DSCN_6703	Down reservoir
	-20		DSCN_6704	Up reservoir
	-20		DSCN_6705	EOT - not at 2m, change in elevation

Date: June 10, 2018		**Project Leader:** Mary Louise Polzin		
Location: Duncan Reservoir			**Field Crew:** Evanne Barret, Dione Louie, Mary Louise Polzin	
S_TR#	**Metre Mark**	**Elevation**	**Image #**	**Description**
S13_Tr720	0	0	DSCN_6750	Herb Plot
	1		DSCN_6751	Looking at POC
	1		DSCN_6752	Looking down line
	1		DSCN_6753	Up reservoir
	1		DSCN_6754	Down reservoir
	20	-2	DSCN_6755	Herb Plot
	21		DSCN_6756	Looking at POC
	21		DSCN_6757	Looking down line
	21		DSCN_6758	Up reservoir
	21		DSCN_6759	Down reservoir
	33	-3	DSCN_6760	Herb Plot
	34		DSCN_6761	Looking at POC
	34		DSCN_6762	Looking down line
	34		DSCN_6763	Up reservoir
	34		DSCN_6764	Down reservoir
	54	-4	DSCN_6765	Herb Plot
	55		DSCN_6766	Looking at POC
	55		DSCN_6767	Looking down line
	55		DSCN_6768	Up reservoir
	55		DSCN_6769	Down reservoir
	85		DSCN_6770	Herb Plot
	86		DSCN_6771	Looking at POC
	86		DSCN_6772	Looking down line
	86		DSCN_6773	Up reservoir
	86		DSCN_6774	Down reservoir
EOT/2012	90		DSCN_6775	Herb Plot
Creek	91		DSCN_6776	Looking at POC
	91		DSCN_6777	Looking down line
	91		DSCN_6778	Up reservoir
	91		DSCN_6779	Down reservoir
EOT/2009	100		DSCN_6780	Herb Plot
	101		DSCN_6781	Looking at POC
	101		DSCN_6782	Looking down line
	101		DSCN_6783	Up reservoir
	101		DSCN_6784	Down reservoir
Upland	-1	0	DSCN_6741	Up line
	-1		DSCN_6742	Down line
	-1		DSCN_6743	Down reservoir
	-1		DSCN_6744	Up reservoir
	-10		DSCN_6745	Up line
	-10		DSCN_6746	Down line
	-10		DSCN_6747	Down reservoir
	-10		DSCN_6748	Up reservoir
	-10		DSCN_6749	EOT - not at 2m, change in elevation

Appendix 6: Photograph Contact Sheets

Duncan Reservoir 2018_Site 1 Transect 1


DSCN5835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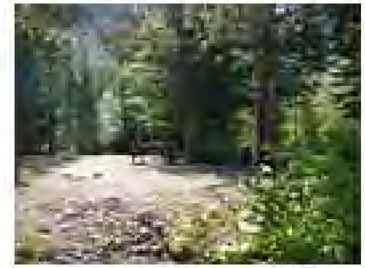
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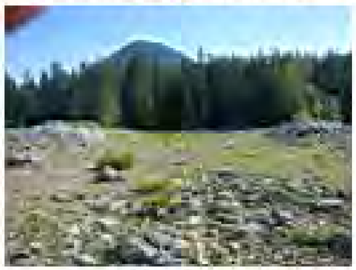
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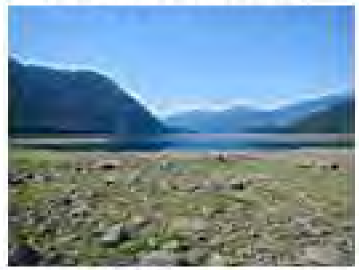
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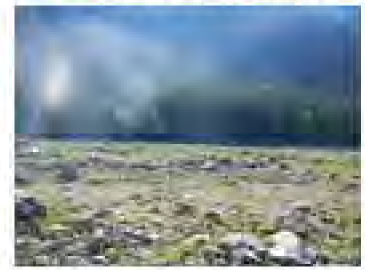
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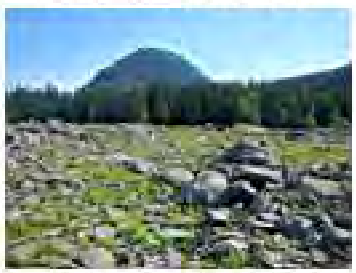
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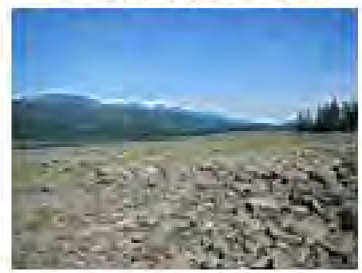
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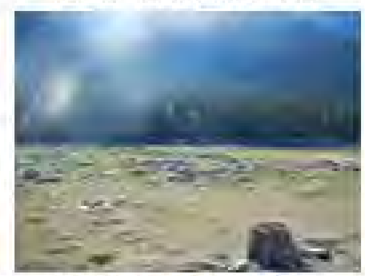
DSCN5853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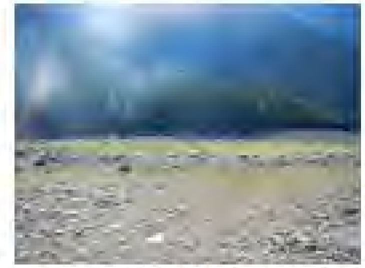
Duncan Reservoir 2018_Site 1 Transect 1


DSCN5855


DSCN5856


DSCN5857


DSCN5858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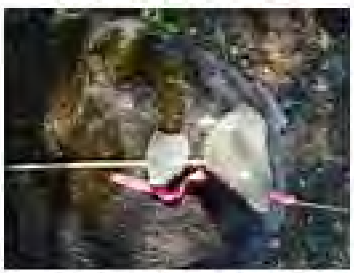
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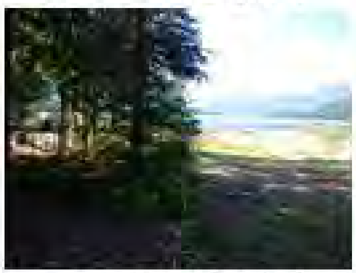
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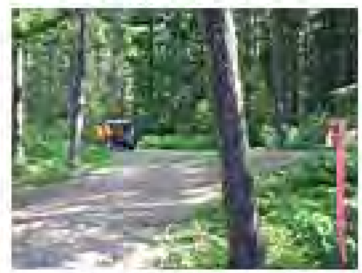
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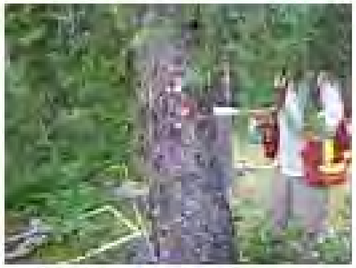
DSCN5869

Duncan Reservoir 2018_Site 1 Transect 869


DSCN5797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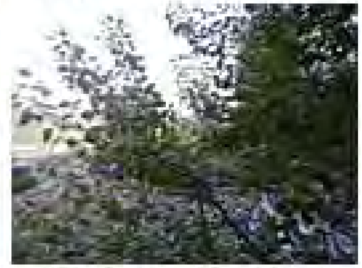
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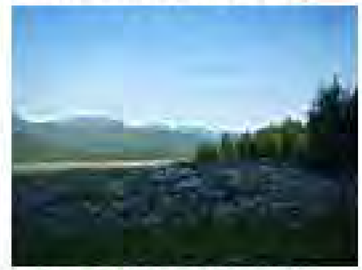
DSCN5801


DSCN5802


DSCN5803


DSCN5804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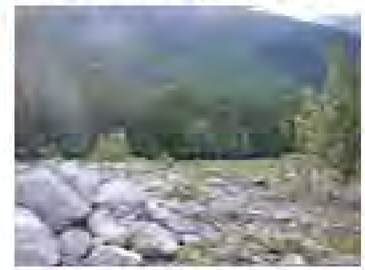
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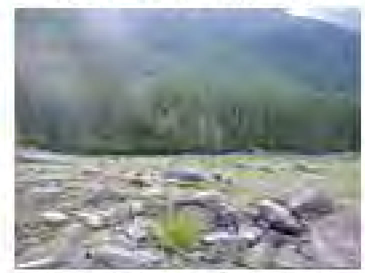
DSCN5808


DSCN5809


DSCN5810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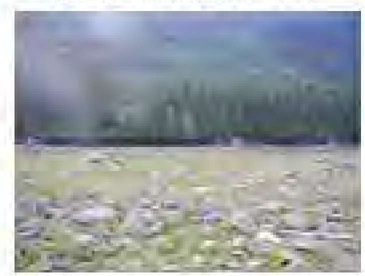
DSCN5813


DSCN5814


DSCN5815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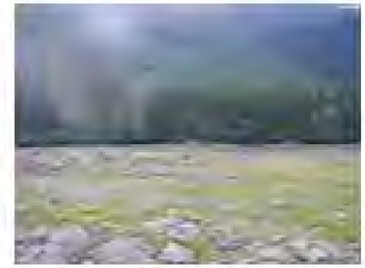
Duncan Reservoir 2018_Site 1 Transect 869


DSCN5817


DSCN5818


DSCN5819


DSCN5820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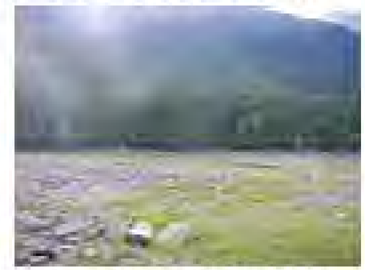
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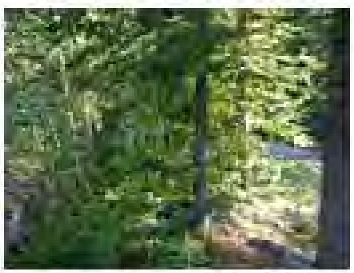
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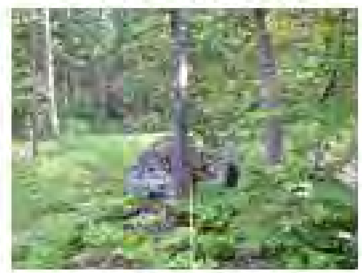
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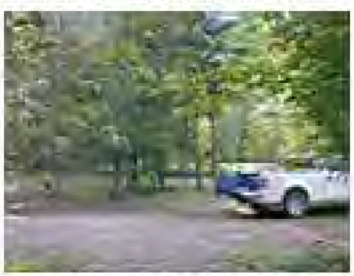
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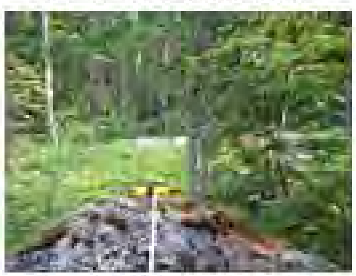
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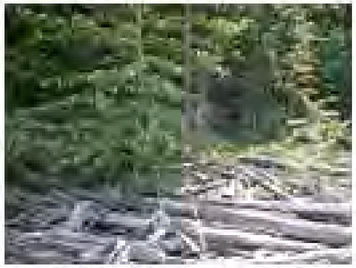
DSCN5834

Duncan Reservoir 2018_Site 2 Transect 822


DSCN5870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DSCN5873


DSCN5874


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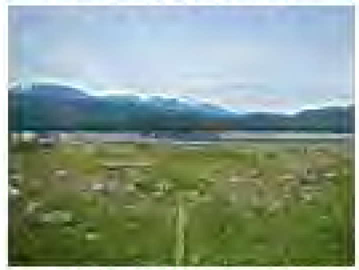
DSCN5876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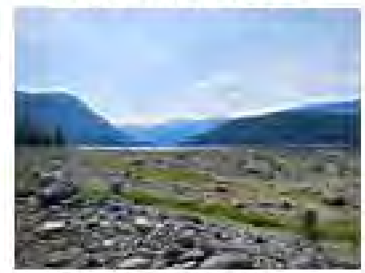
DSCN5883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DSCN5888


DSCN5889

Duncan Reservoir 2018_Site 2 Transect 822


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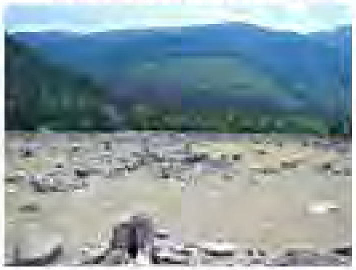
DSCN5893


DSCN5894


DSCN5895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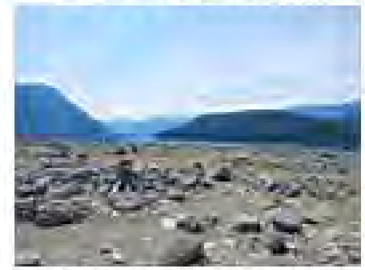
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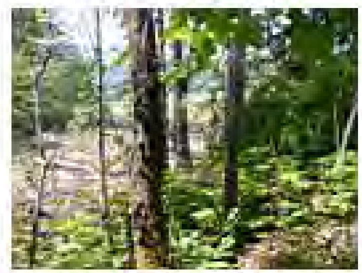
DSCN5900


DSCN5901


DSCN5902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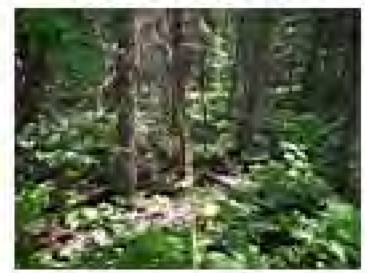
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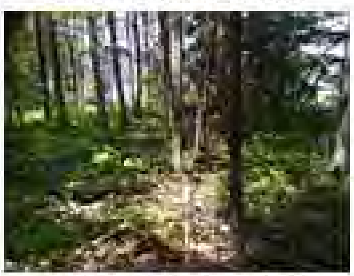
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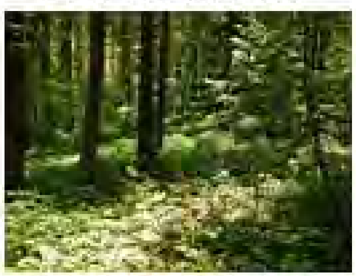
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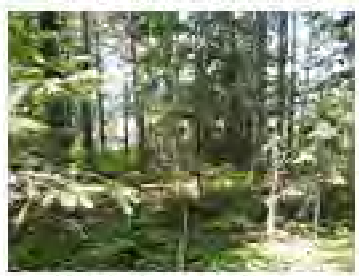
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DSCN5908

Duncan Reservoir 2018_Site 2 Transect 884


DSCN5909


DSCN5910

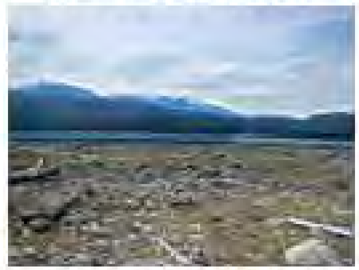

DSCN5911


DSCN5912


DSCN5913


DSCN5914


DSCN5915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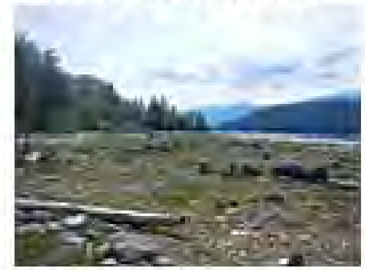
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DSCN5920


DSCN5921


DSCN5922


DSCN5923


DSCN5924


DSCN5925

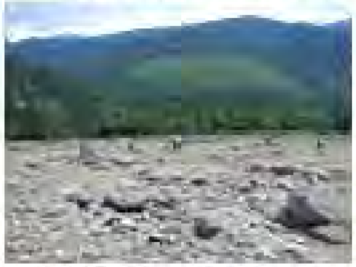

DSCN5926


DSCN5927


DSCN5928

Duncan Reservoir 2018_Site 2 Transect 884


DSCN5929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DSCN5932


DSCN5933


DSCN5934


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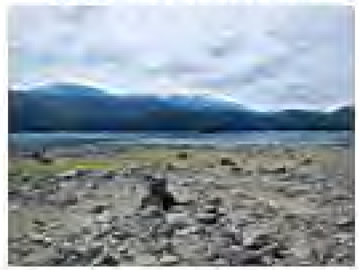
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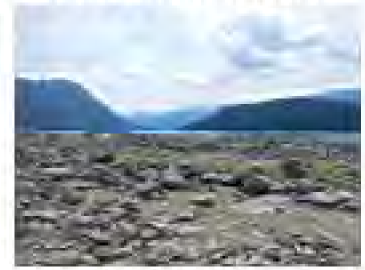
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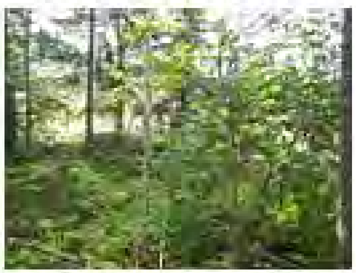
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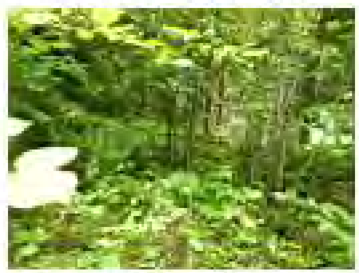
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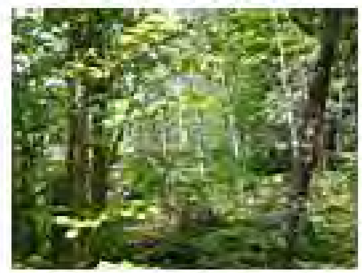
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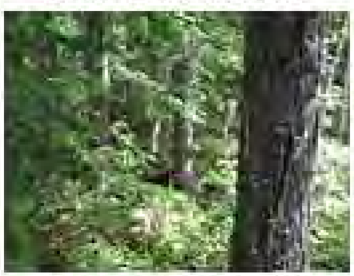
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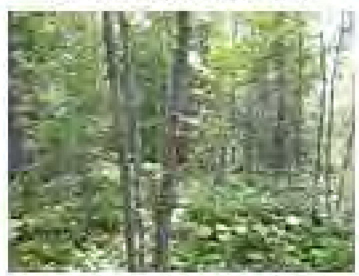
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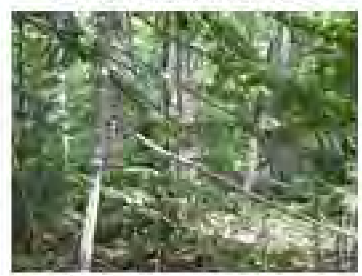
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Duncan Reservoir 2018_Site 2 Transect 885


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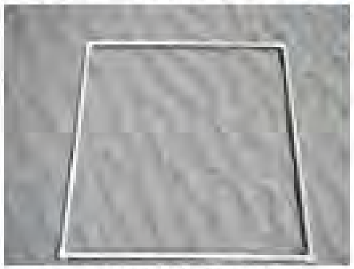
DSCN5949


DSCN5950


DSCN5951


DSCN5952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DSCN5956


DSCN5957


DSCN5958


DSCN5959


DSCN5960


DSCN5961


DSCN5962


DSCN5963


DSCN5964


DSCN5965


DSCN5966


DSCN5967

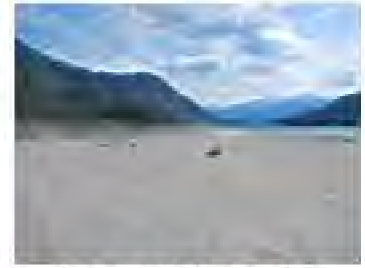
Duncan Reservoir 2018_Site 2 Transect 885


DSCN5968


DSCN5969


DSCN5970


DSCN5971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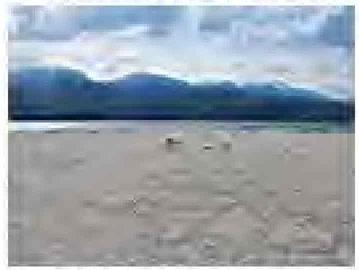
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DSCN5977


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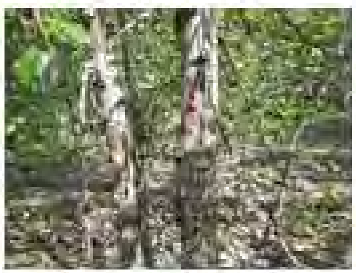
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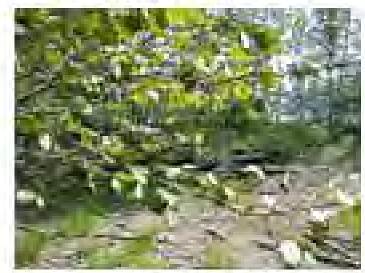
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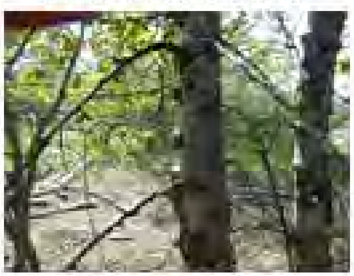
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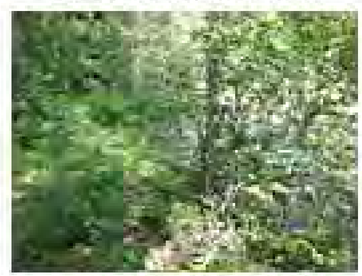
DSCN5984


DSCN5985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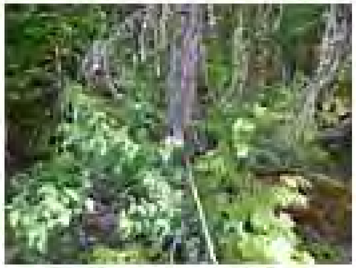
Duncan Reservoir 2018_Site 3 Transect 704


DSCN6023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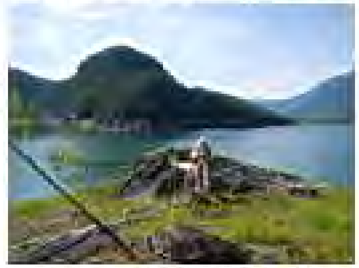
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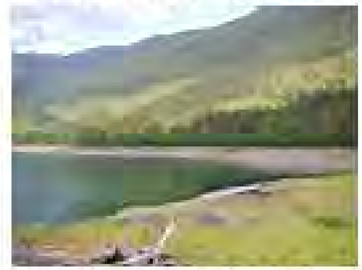
DSCN6030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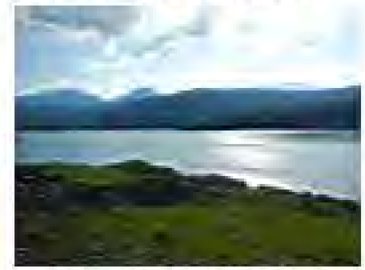
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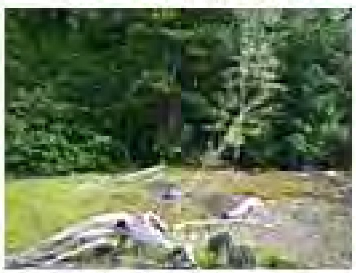
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DSCN6035


DSCN6036


DSCN6037


DSCN6038


DSCN6039


DSCN6040


DSCN6041


DSCN6042

Duncan Reservoir 2018_Site 3 Transect 704


DSCN6043


DSCN6044


DSCN6045


DSCN6046


DSCN6047


DSCN6048

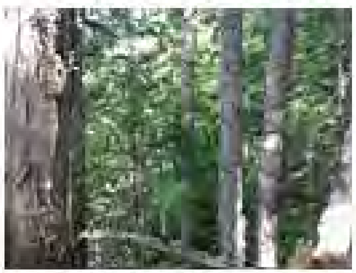

DSCN6049


DSCN6050


DSCN6051


DSCN6052


DSCN6053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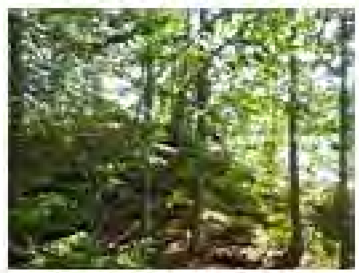
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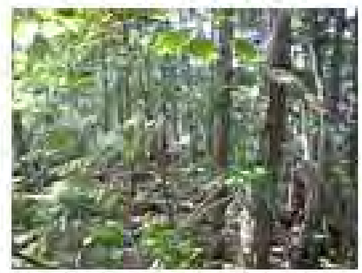
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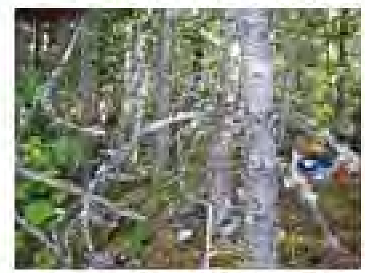
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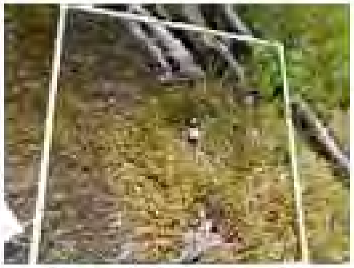
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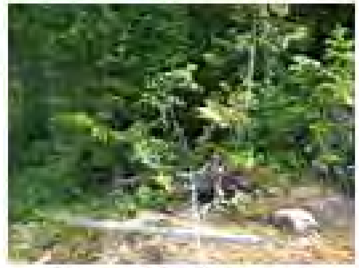
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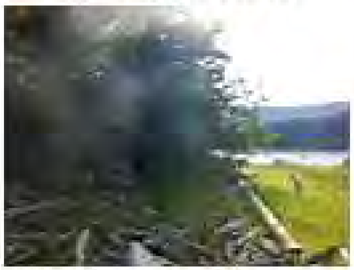
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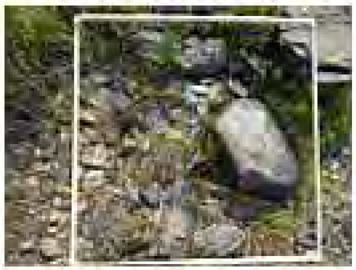
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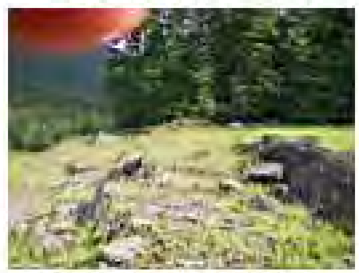
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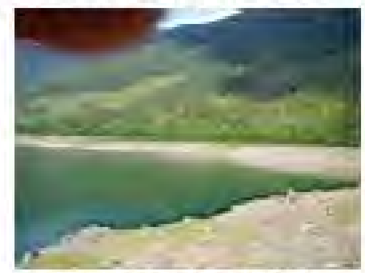
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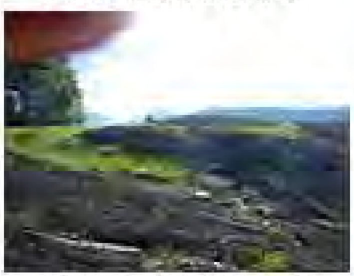
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DSCN6006

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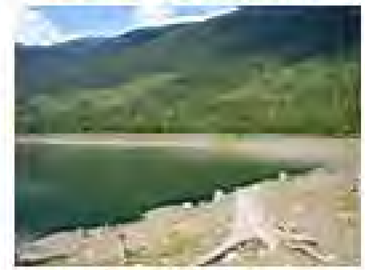
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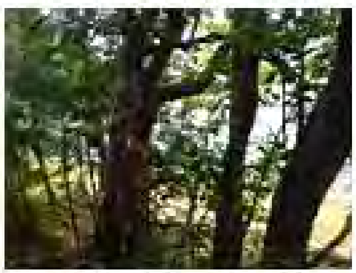
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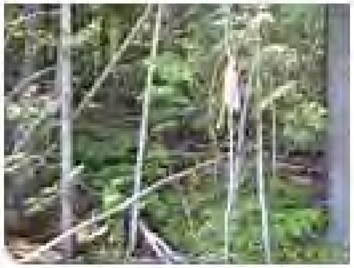
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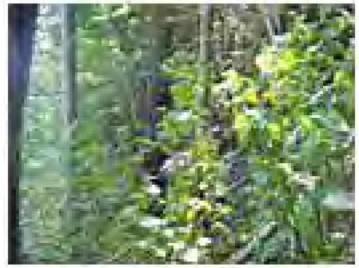
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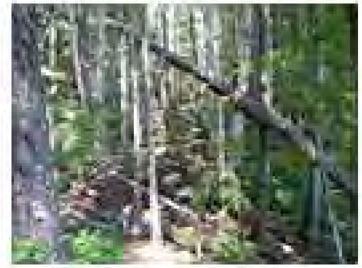
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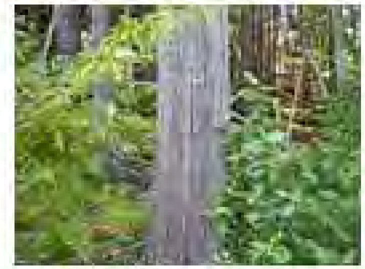
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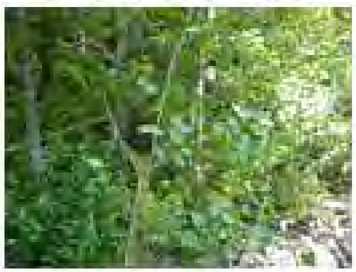
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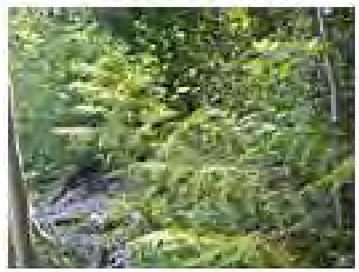
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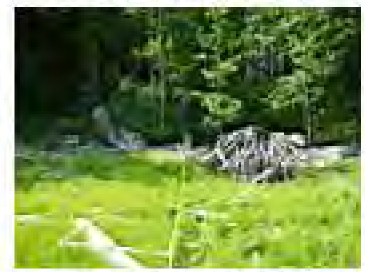
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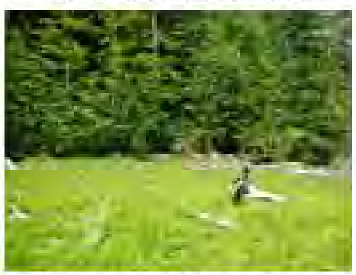
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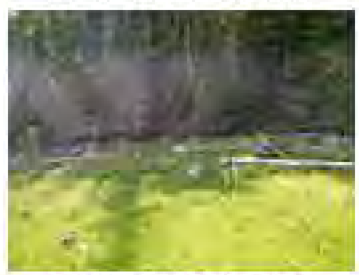
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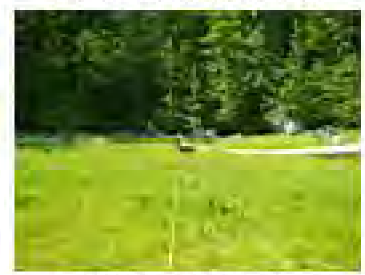
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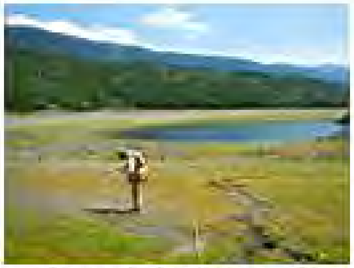
Duncan Reservoir 2018_Site 4 Transect 705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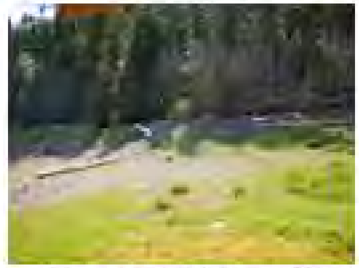
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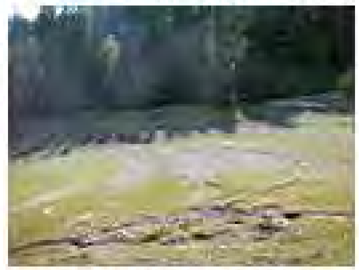
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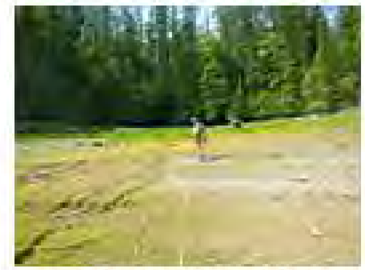
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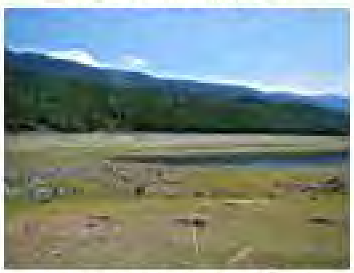
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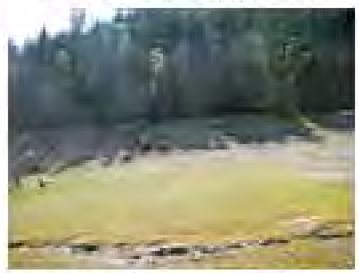
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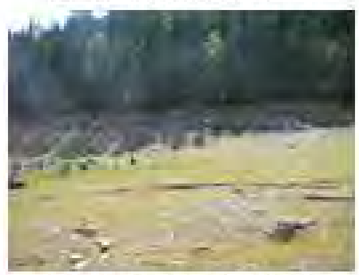
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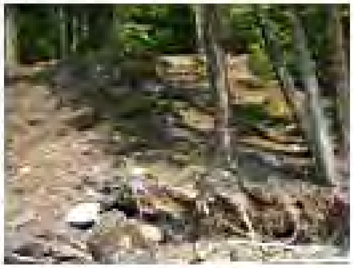
Duncan Reservoir 2018_Site 4 Transect 706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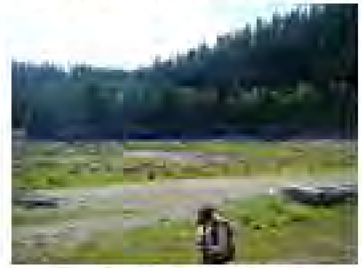
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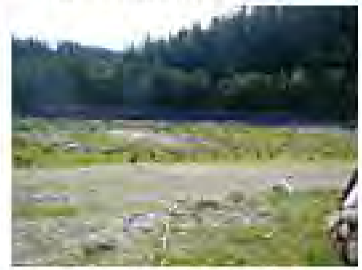
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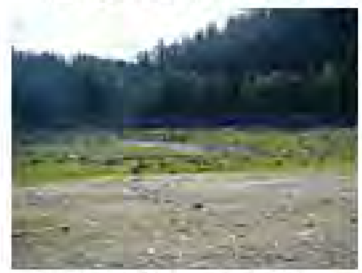
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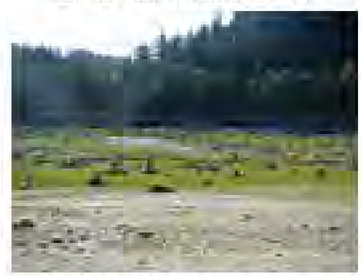
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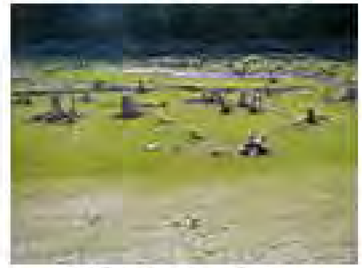
DSCN5786


DSCN5787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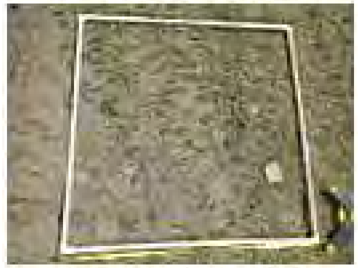
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Duncan Reservoir 2018_Site 5 Transect 707


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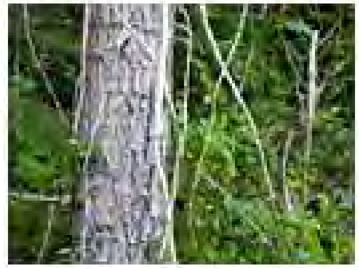
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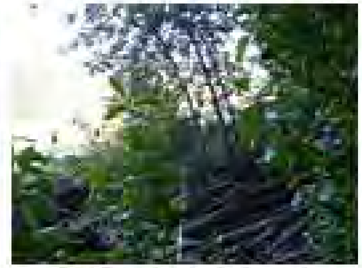
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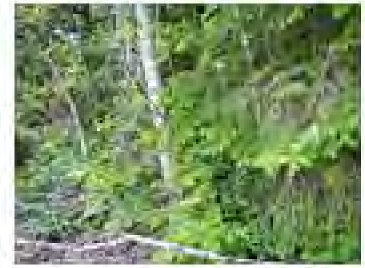
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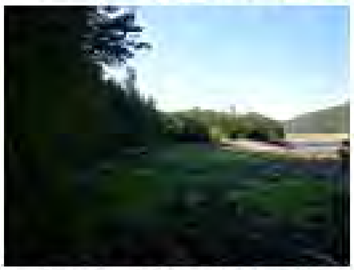
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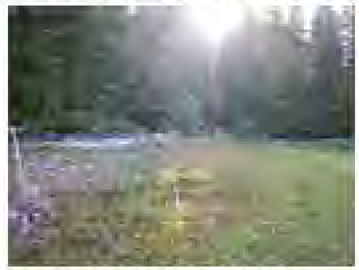
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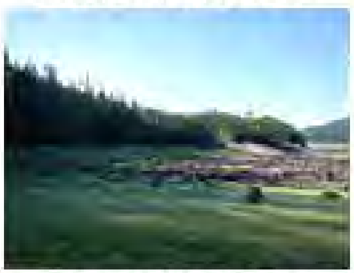
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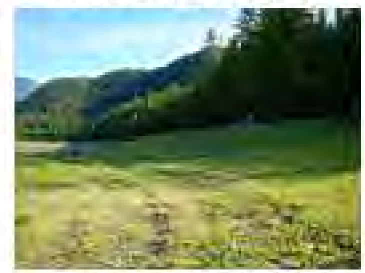
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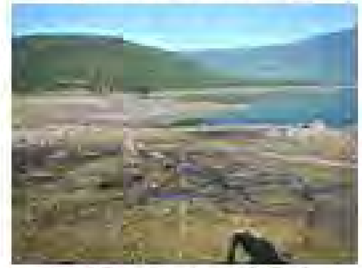
DSCN6079


DSCN6080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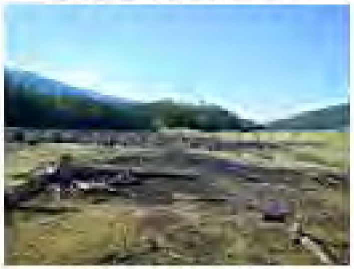
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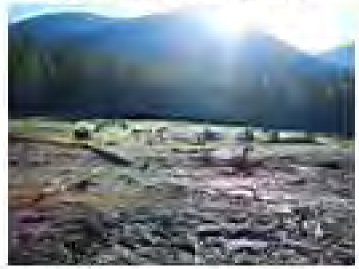
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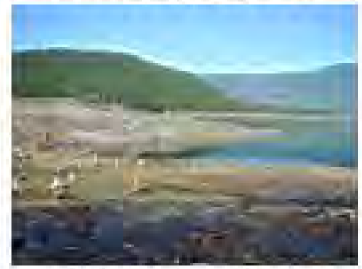
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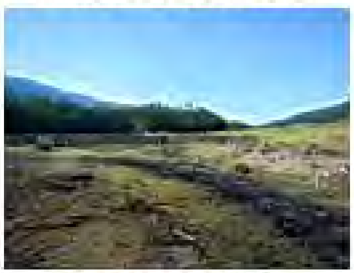
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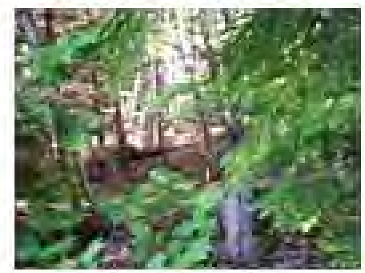
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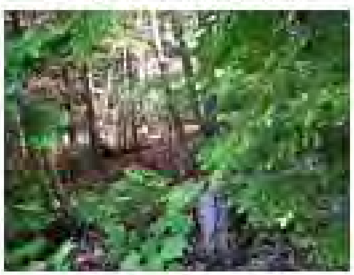
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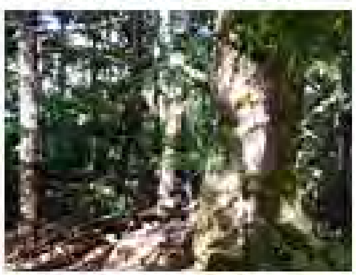
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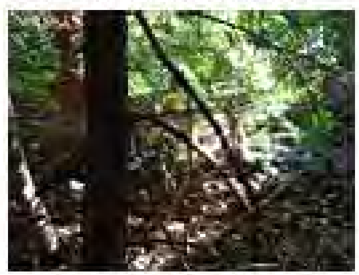
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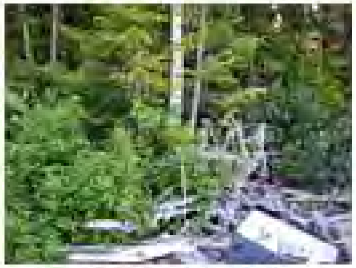
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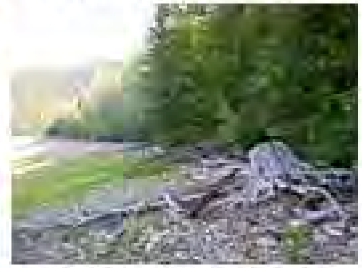
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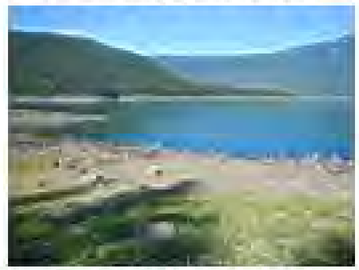
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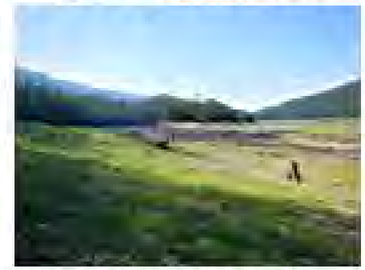
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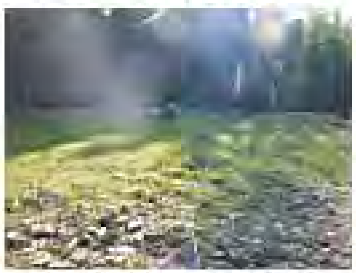
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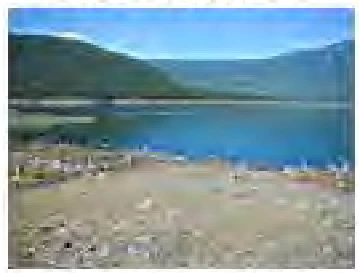
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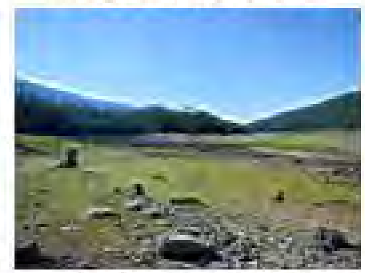
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DSCN6114


DSCN6115

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DSCN6116


DSCN6117

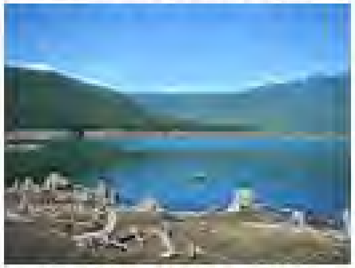

DSCN6118


DSCN6119


DSCN6120


DSCN6121


DSCN6122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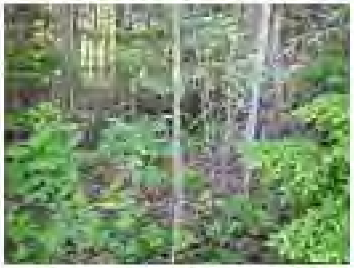
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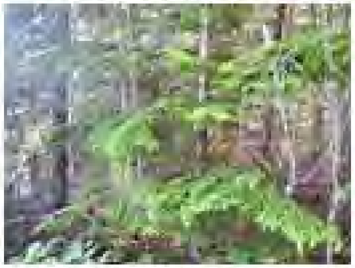
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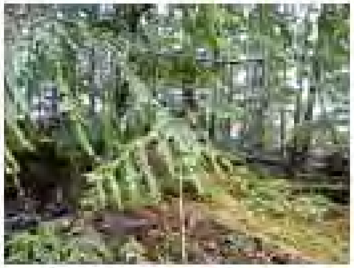
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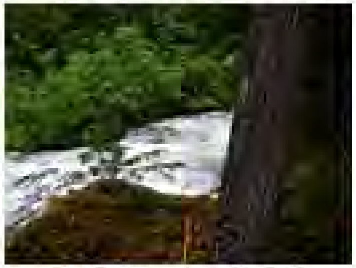
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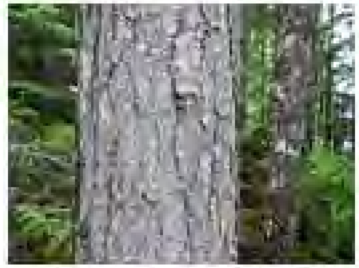
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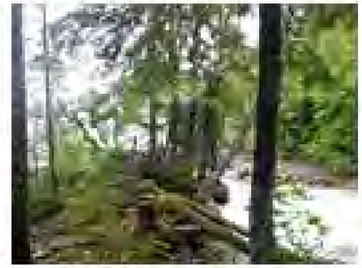
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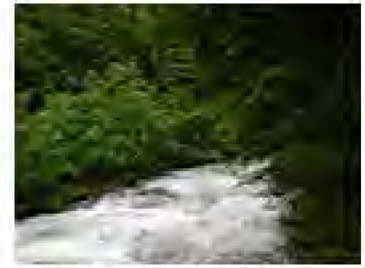
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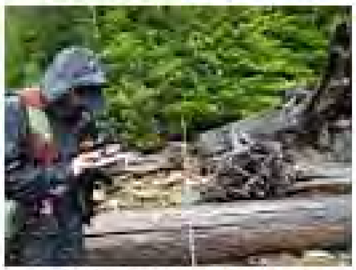
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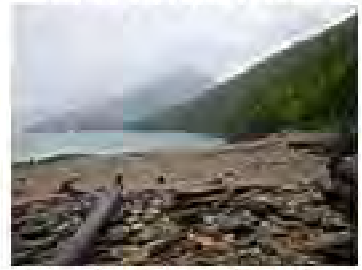
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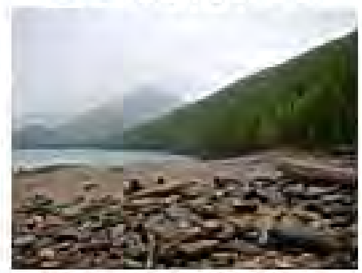
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Duncan Reservoir 2018_Site 6 Transect 708

				
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				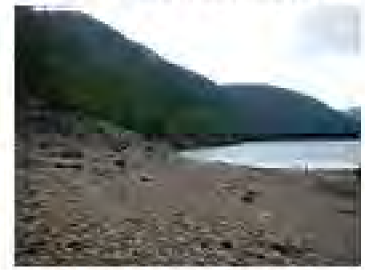
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DSCN6821


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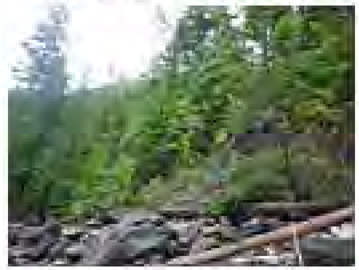
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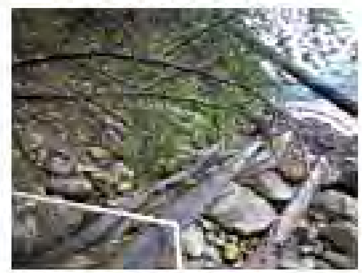
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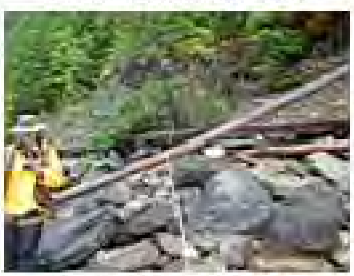
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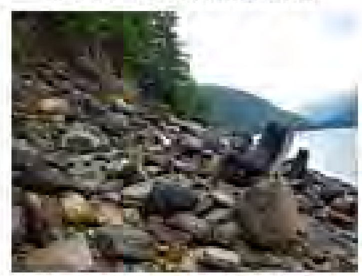
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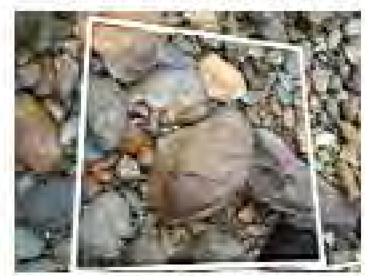
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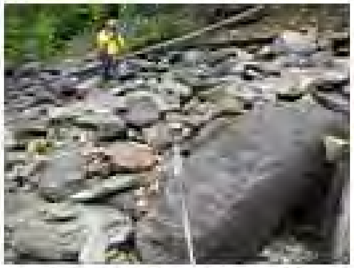
Duncan Reservoir 2018_Site 6 Transect 814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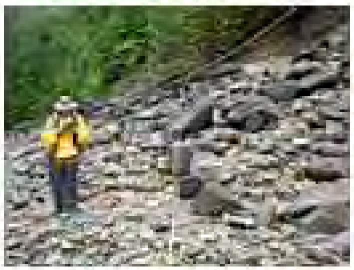
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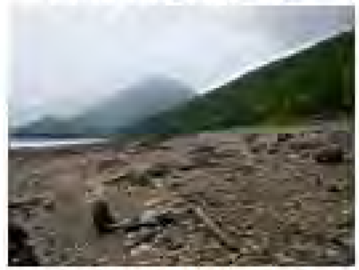
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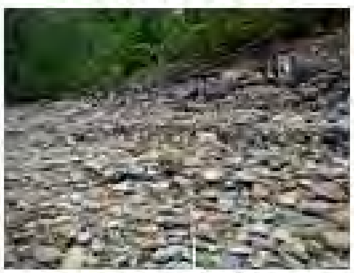
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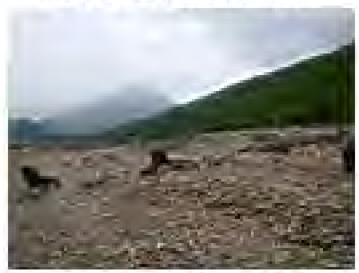
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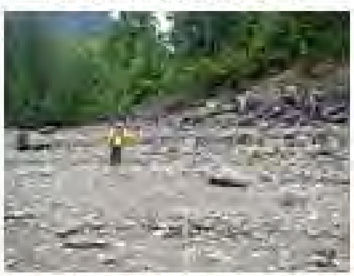
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Duncan Reservoir 2018_Site 7 Transect 2


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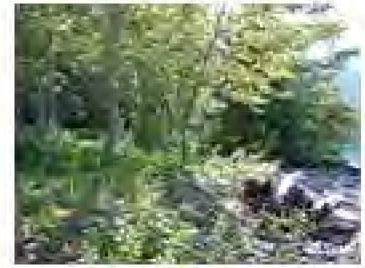
DSCN6134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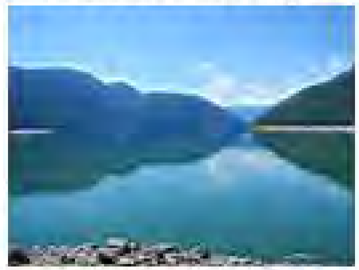
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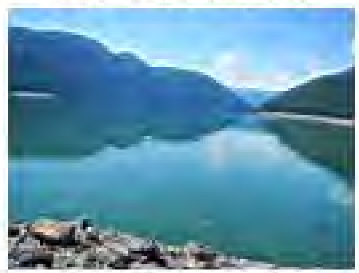
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Duncan Reservoir 2018_Site 7 Transect 2


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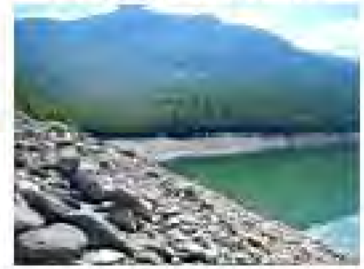
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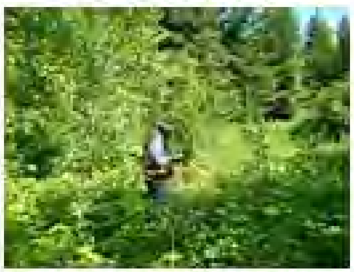
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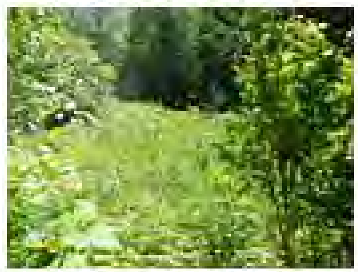
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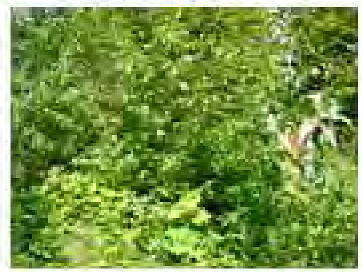
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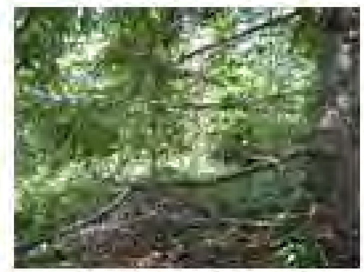
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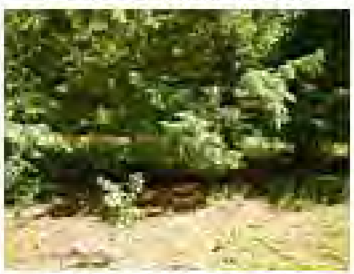
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Duncan Reservoir 2018_Site 7 Transect 3


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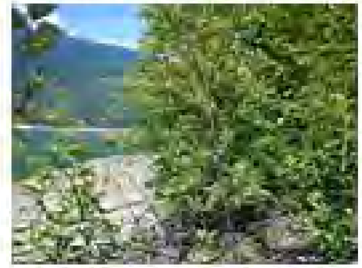
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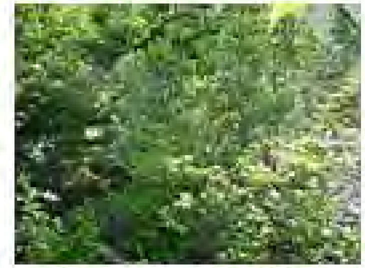
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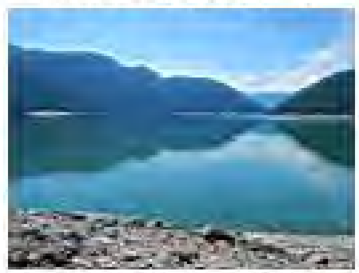
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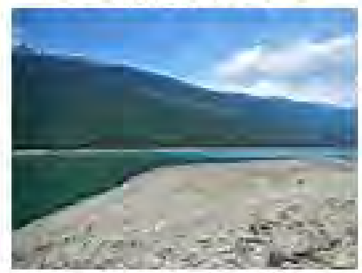
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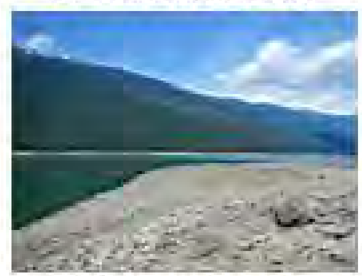
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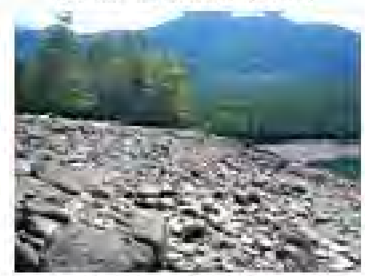
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Duncan Reservoir 2018_Site 7 Transect 3


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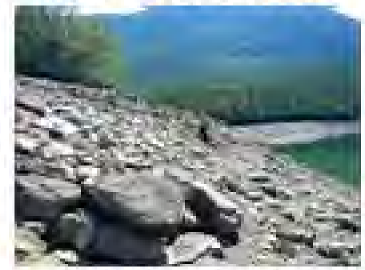
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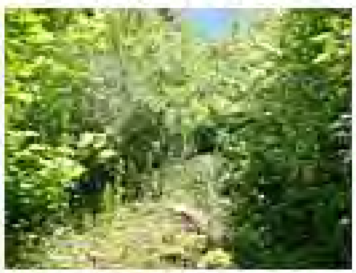
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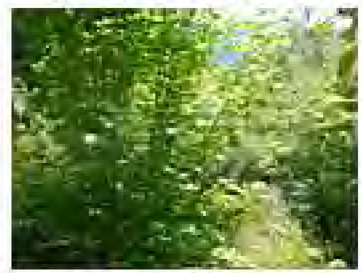
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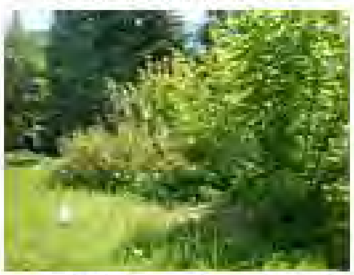
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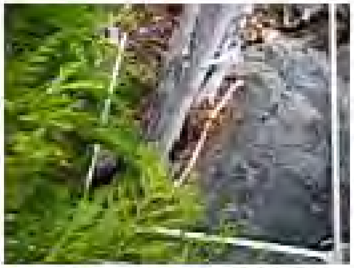
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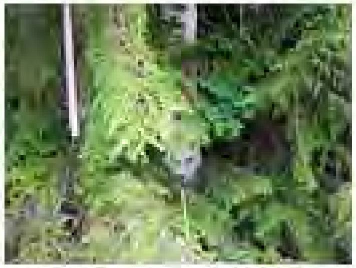
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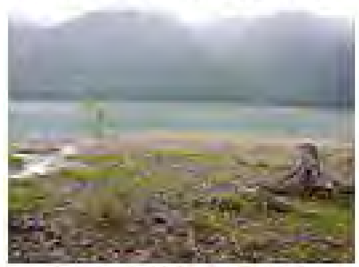
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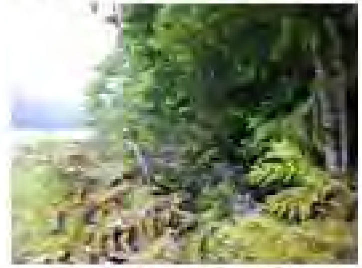
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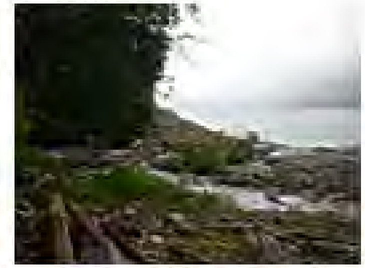
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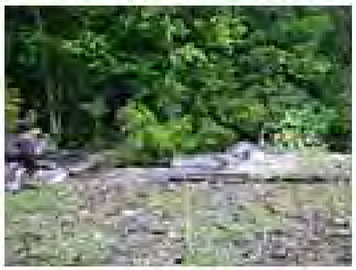
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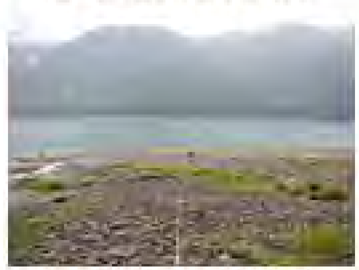
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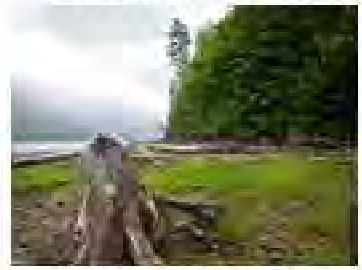
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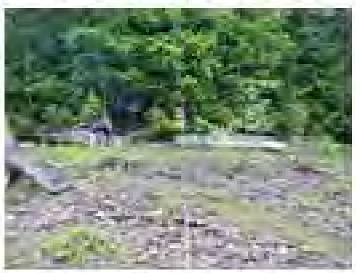
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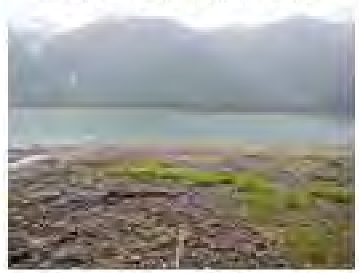
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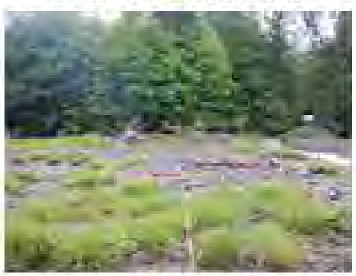
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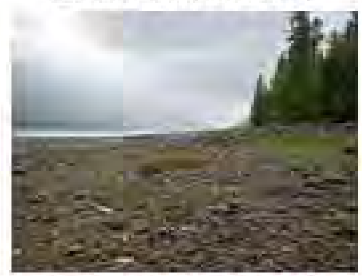
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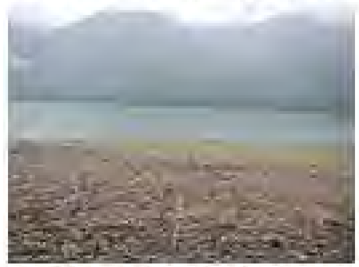
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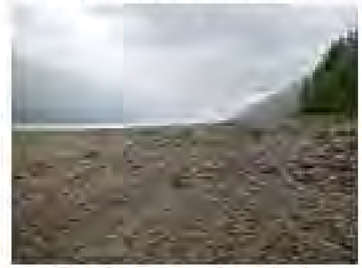
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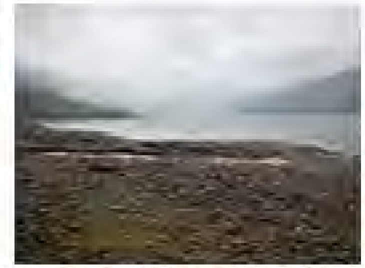
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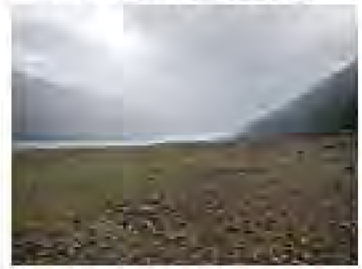
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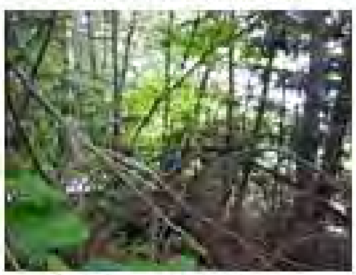
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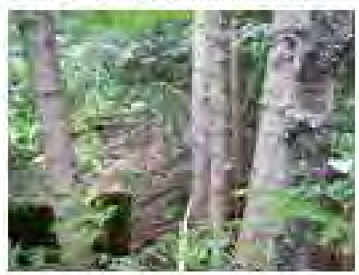
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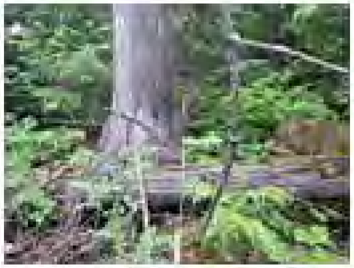
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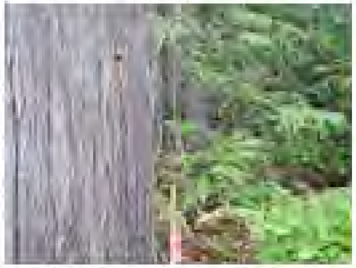
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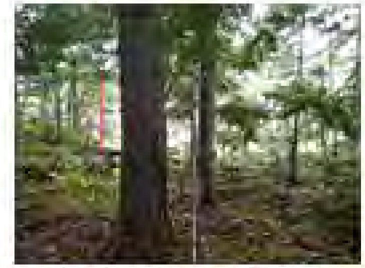
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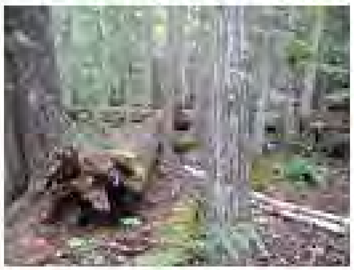
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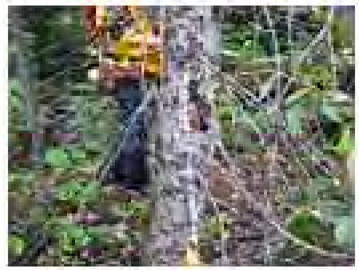
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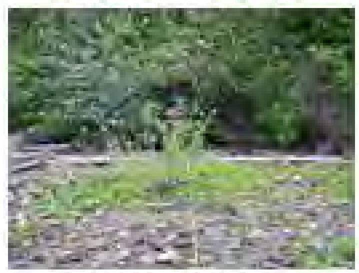
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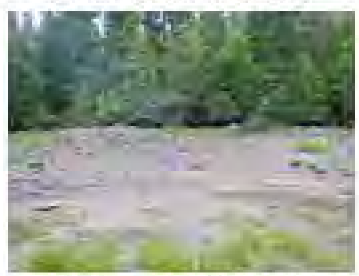
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DSCN6564


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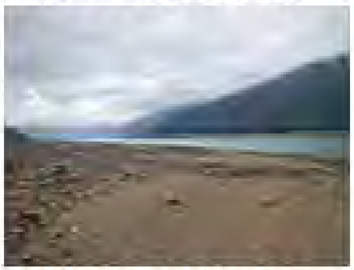
DSCN6566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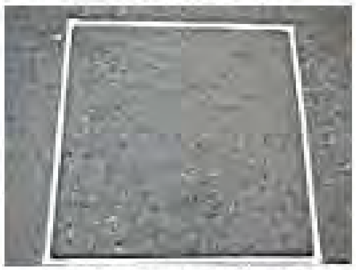
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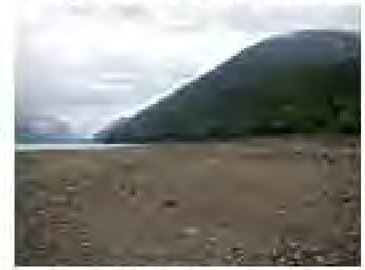
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Duncan Reservoir 2018_Site 9 Transect 711


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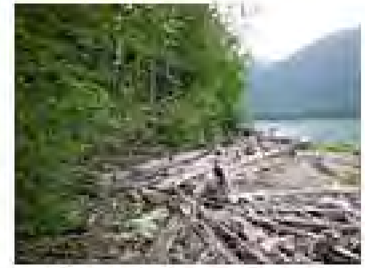
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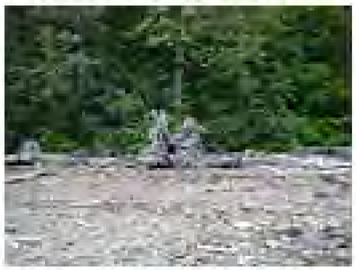
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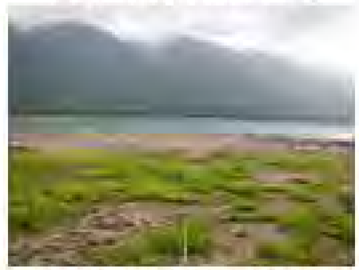
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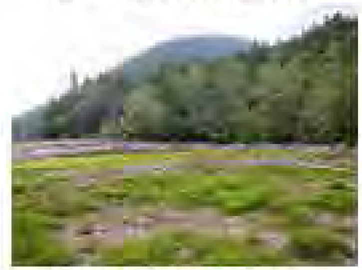
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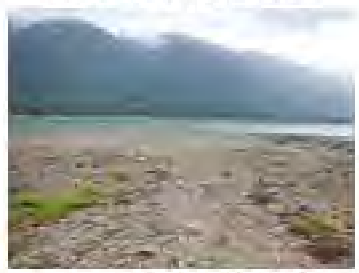
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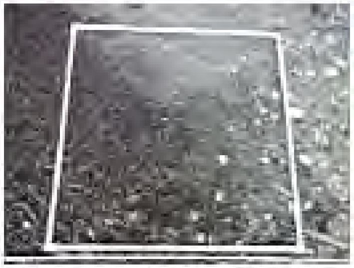
Duncan Reservoir 2018_Site 9 Transect 711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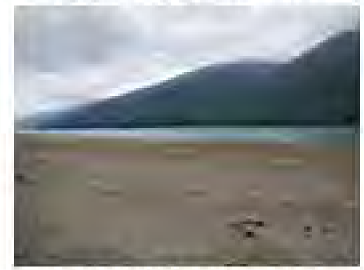
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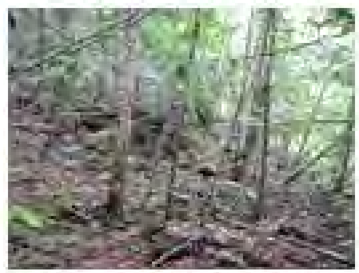
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Duncan Reservoir 2018_Site 9 Transect 712


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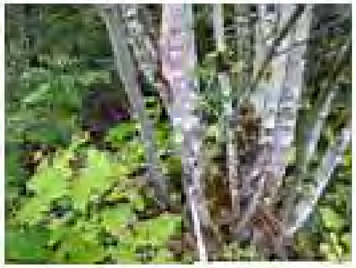
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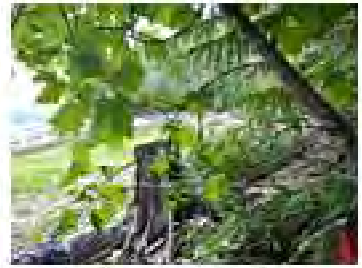
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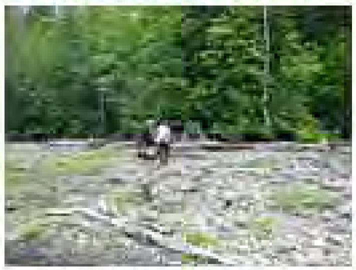
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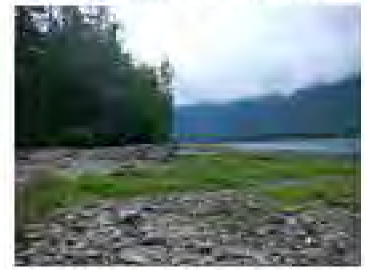
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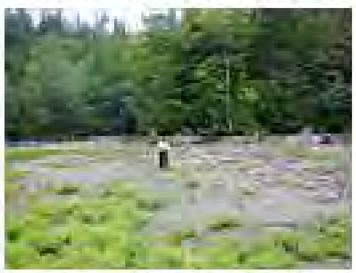
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DSCN6479

Duncan Reservoir 2018_Site 9 Transect 712


DSCN6480


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DSCN6483


DSCN6484


DSCN6485


DSCN6486


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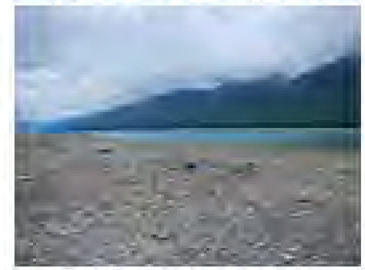
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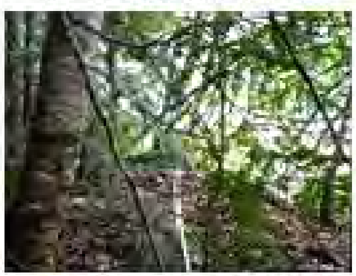
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Duncan Reservoir 2018_Site 10 Transect 714


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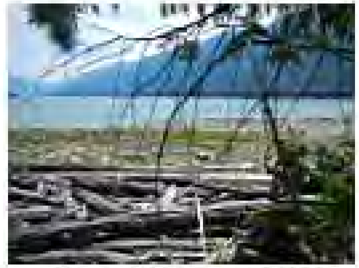
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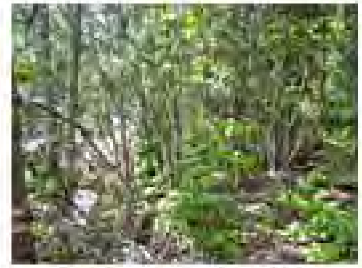
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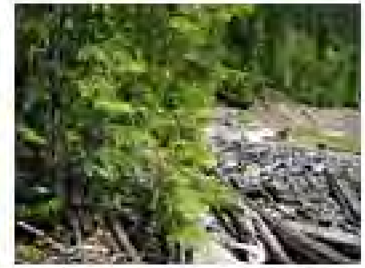
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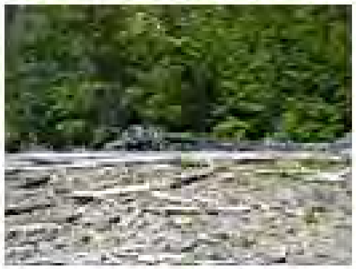
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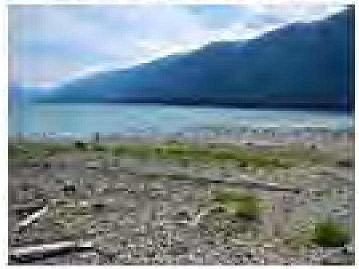
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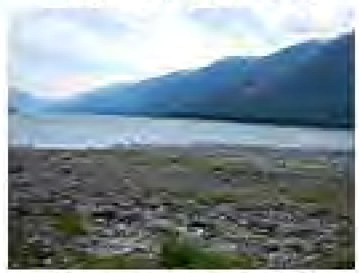
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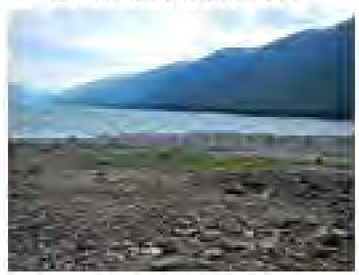
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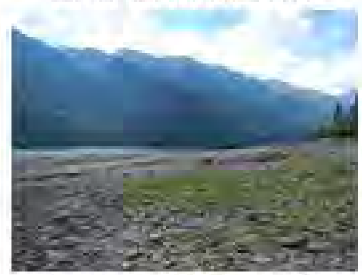
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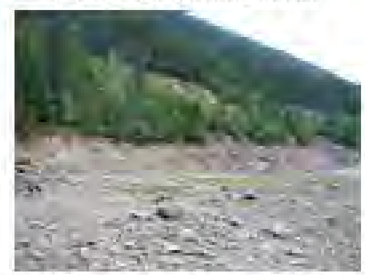
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Duncan Reservoir 2018_Site 10 Transect 714


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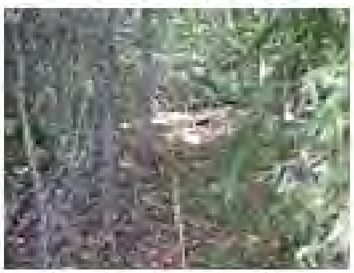
DSCN6304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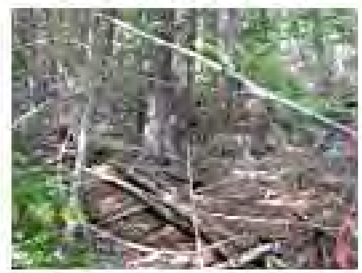
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Duncan Reservoir 2018_Site 10 Transect 713


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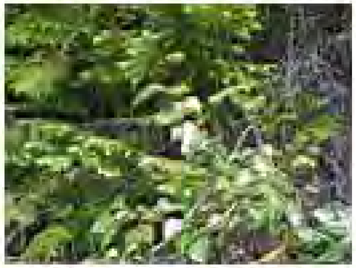
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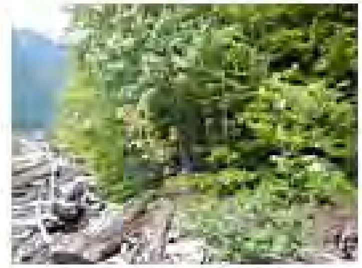
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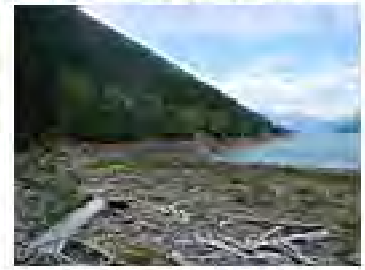
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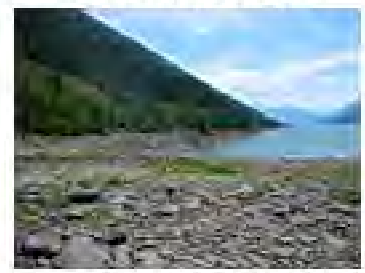
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Duncan Reservoir 2018_Site 10 Transect 713


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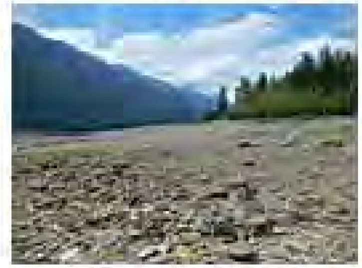
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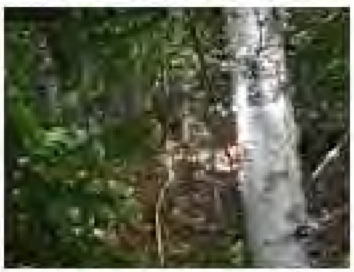
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Duncan Reservoir 2018_Site 10 Transect 6

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DSCN6205

DSCN6206

DSCN6207

DSCN6208

DSCN6209

DSCN6210

DSCN6211

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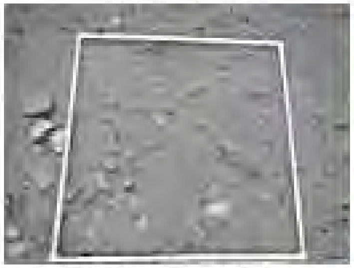
Duncan Reservoir 2018_Site 10 Transect 6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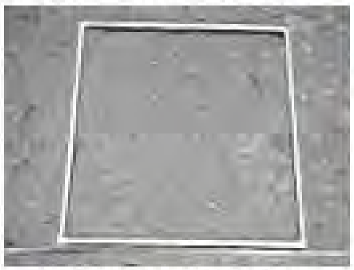
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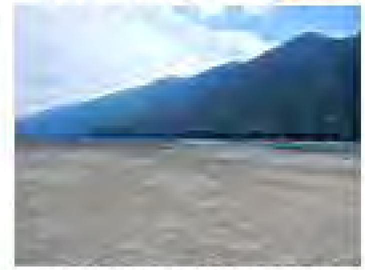
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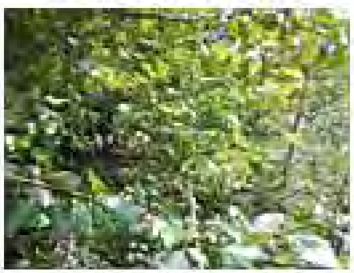
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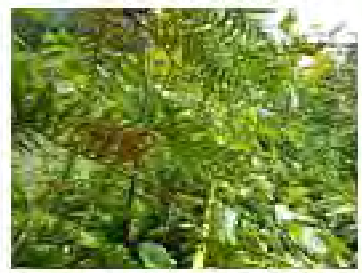
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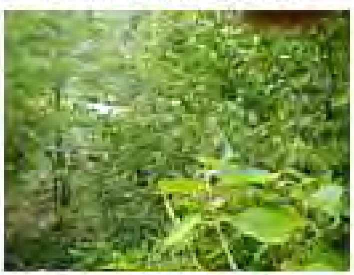
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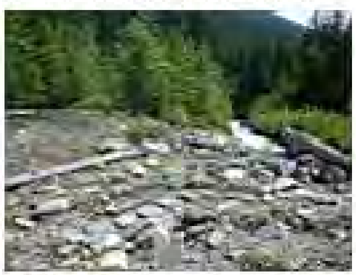
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Duncan Reservoir 2018_Site 11 Transect 715


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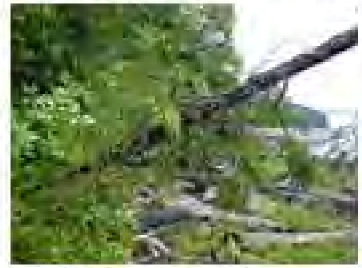
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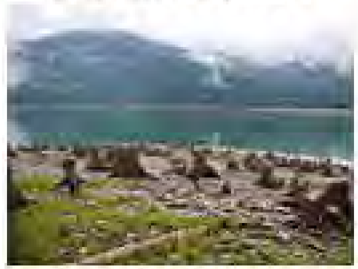
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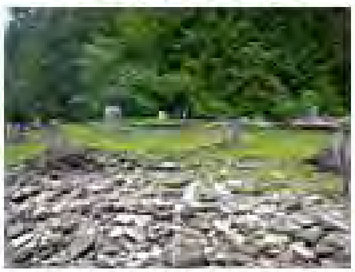
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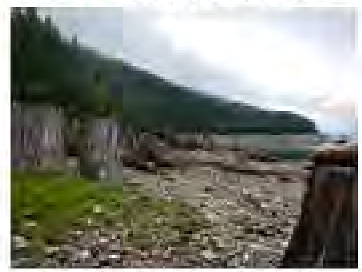
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Duncan Reservoir 2018_Site 11 Transect 715


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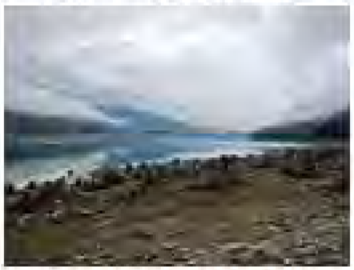
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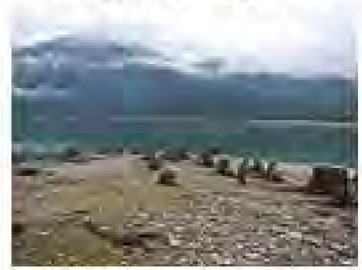
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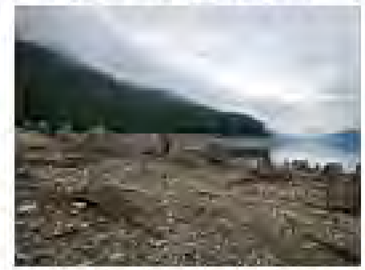
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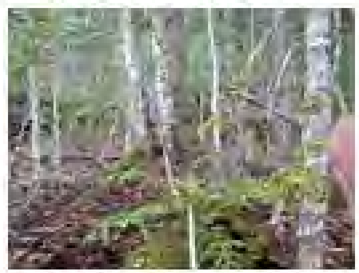
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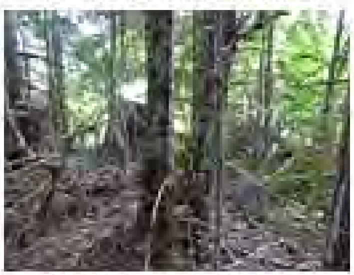
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Duncan Reservoir 2018_Site 11 Transect 716


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DSCN6320


DSCN6321


DSCN6322


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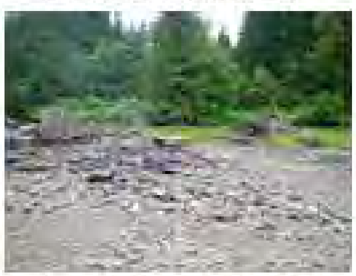
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Duncan Reservoir 2018_Site 11 Transect 716

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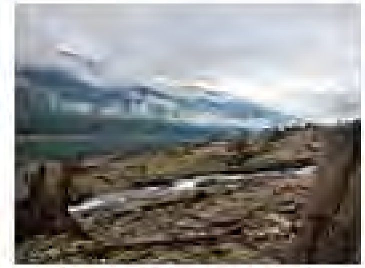

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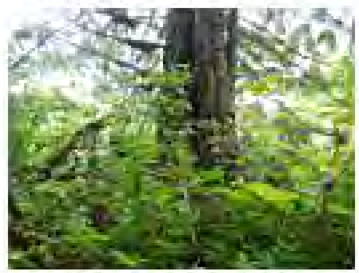

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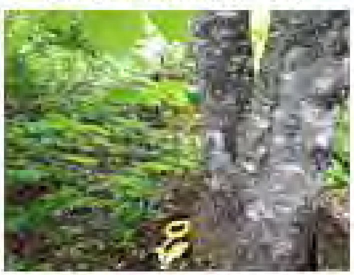

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Duncan Reservoir 2018_Site 12 Transect 718


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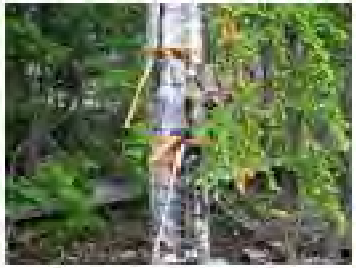
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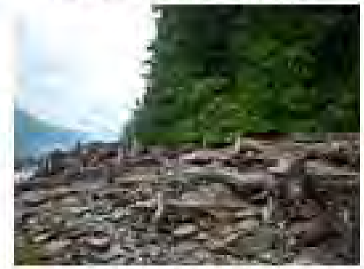
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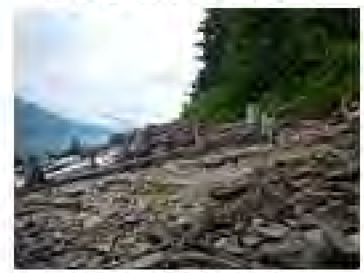
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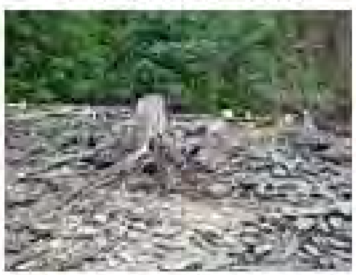
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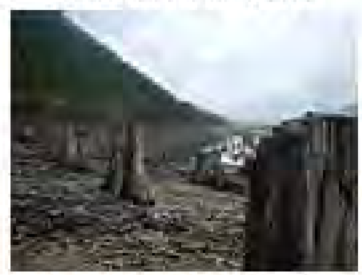
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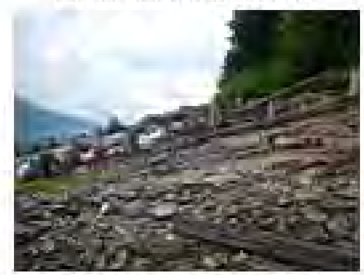
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Duncan Reservoir 2018_Site 12 Transect 718


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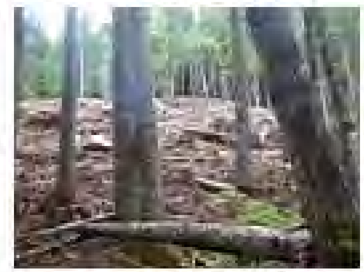
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Duncan Reservoir 2018_Site 12 Transect 5


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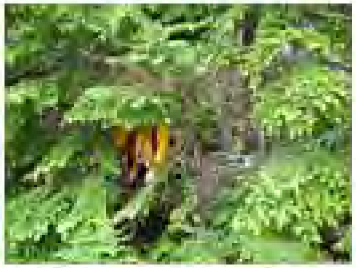
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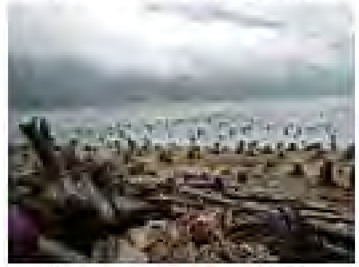
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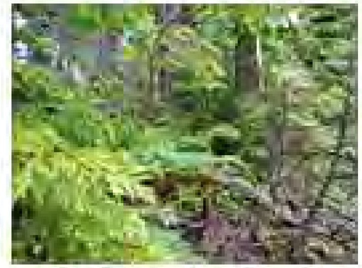
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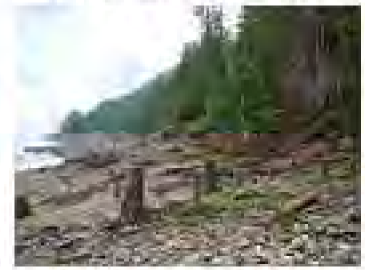
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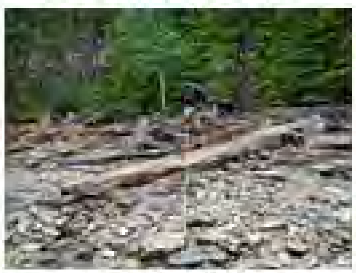
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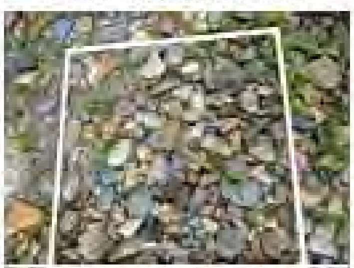
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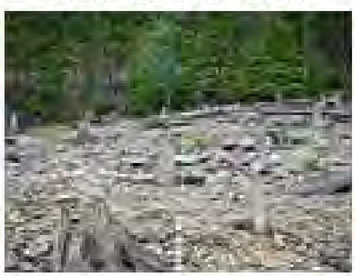
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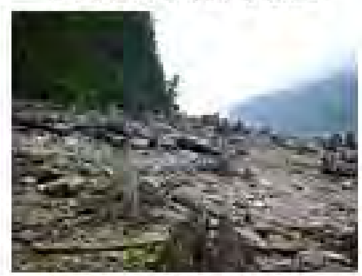
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Duncan Reservoir 2018_Site 12 Transect 5


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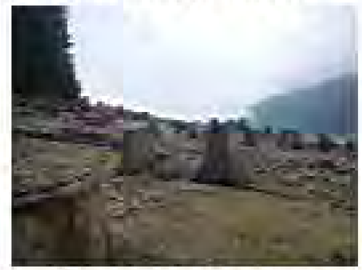
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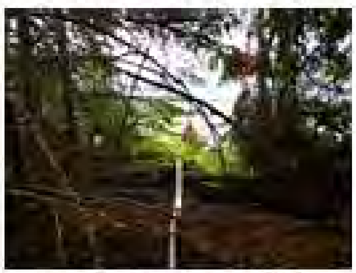
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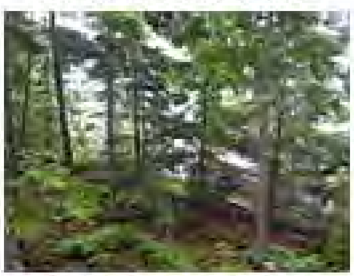
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Duncan Reservoir 2018_Site 13 Transect 717


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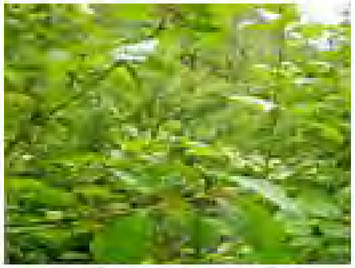
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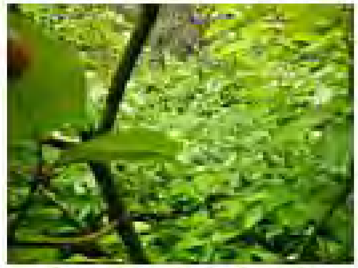
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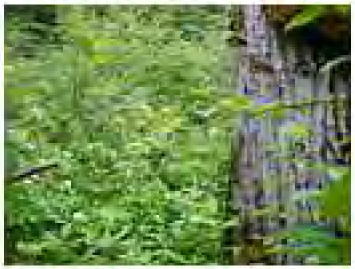
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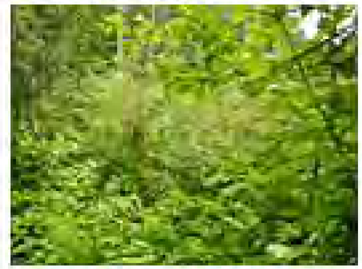
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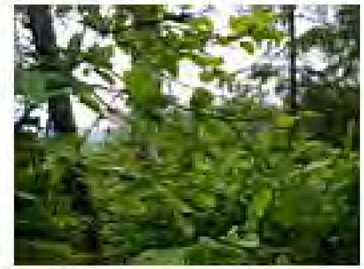
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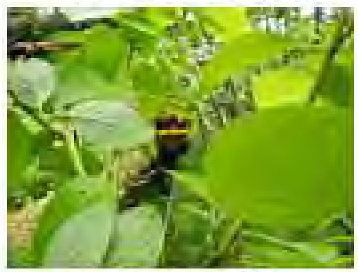
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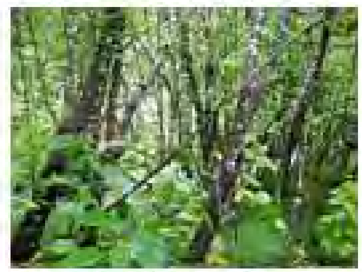
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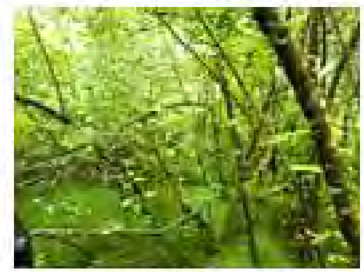
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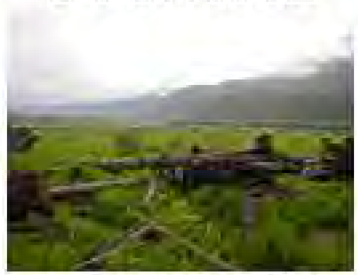
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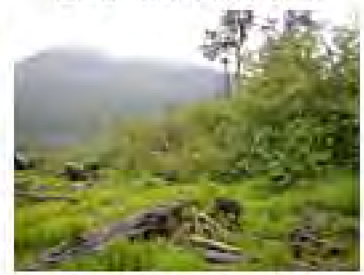
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Duncan Reservoir 2018_Site 13 Transect 717


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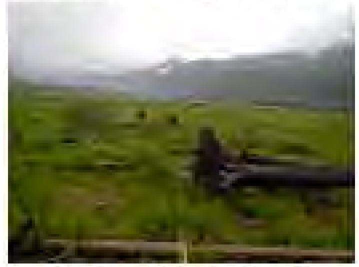
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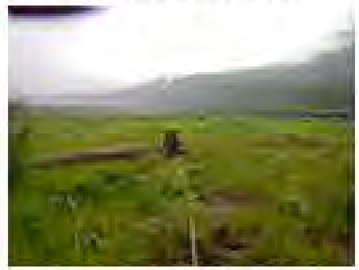
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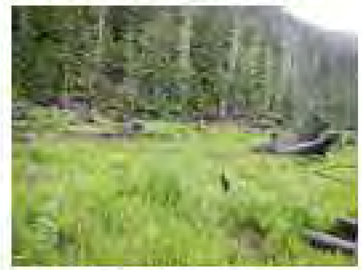
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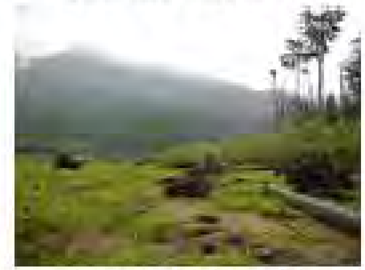
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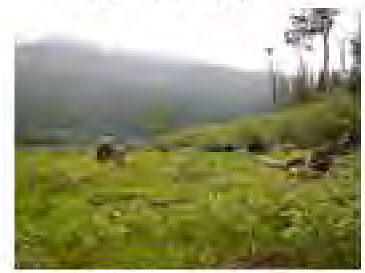
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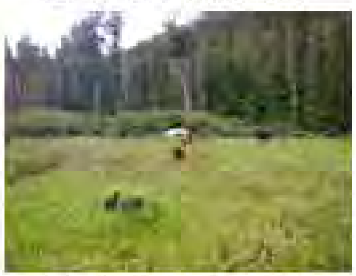
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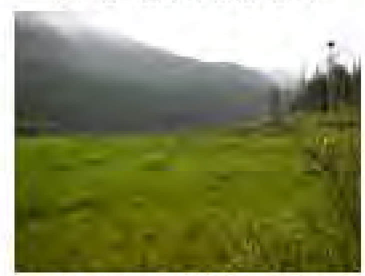
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Duncan Reservoir 2018_Site 13 Transect 4


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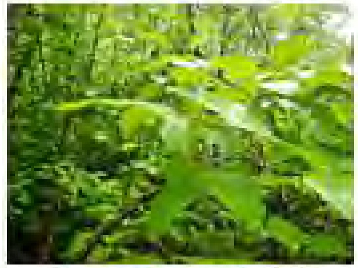
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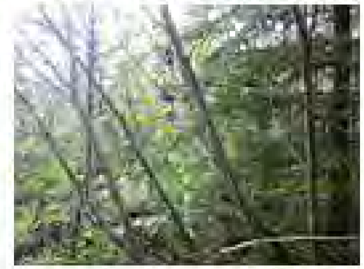
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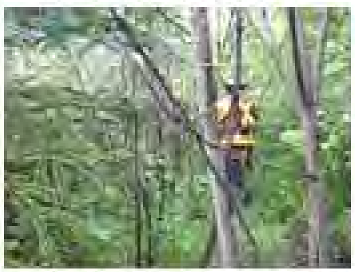
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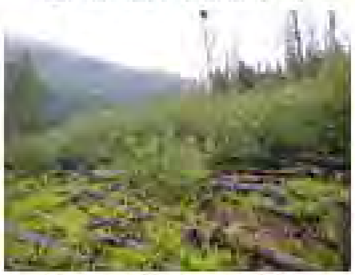
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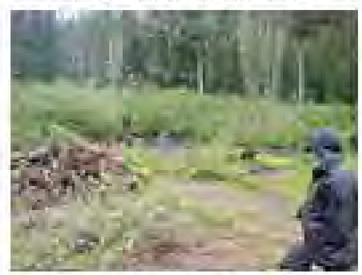
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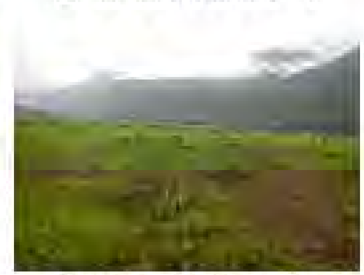
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Duncan Reservoir 2018_Site 13 Transect 4


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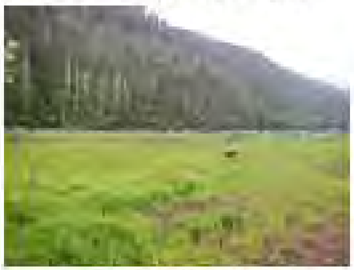
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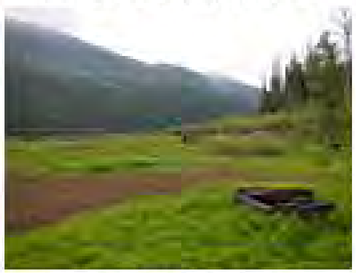
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Duncan Reservoir 2018_Site 13 Transect 719

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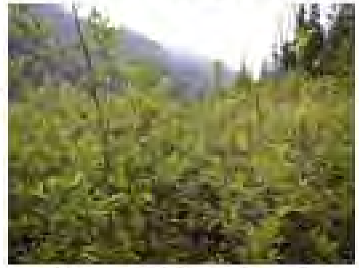

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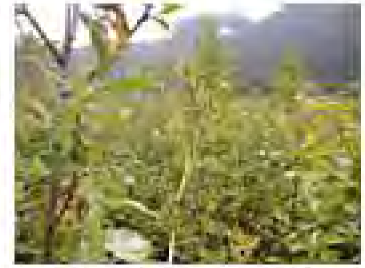

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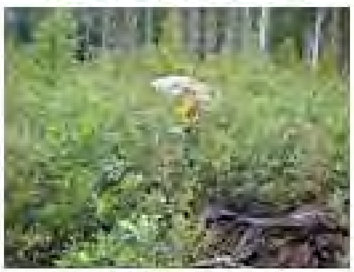

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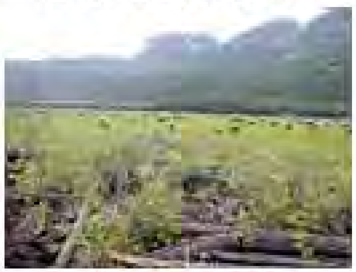

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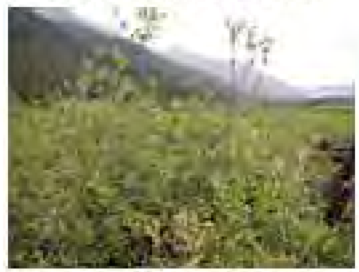

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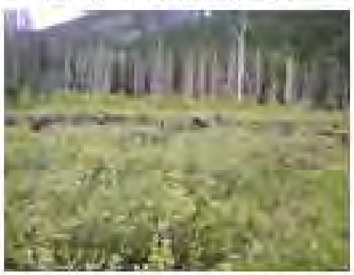

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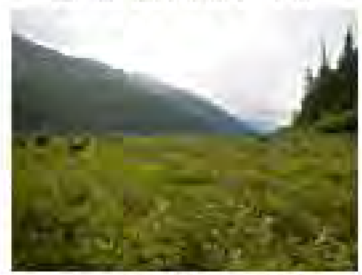

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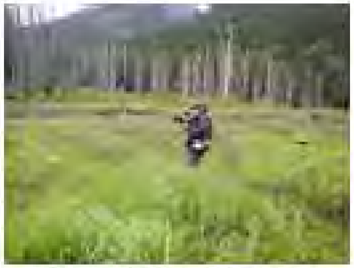
Duncan Reservoir 2018_Site 13 Transect 719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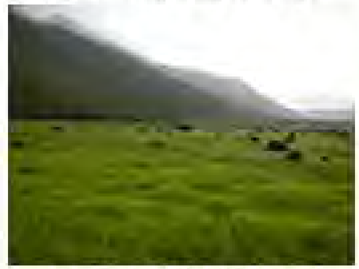
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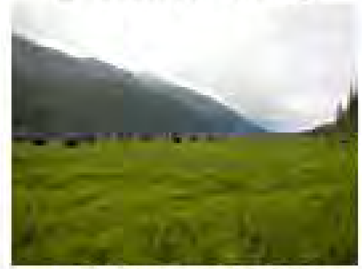
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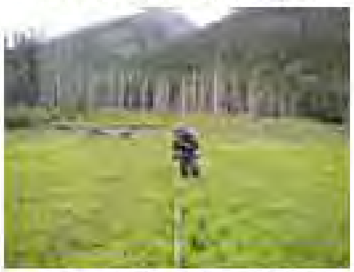
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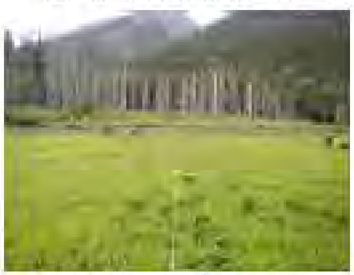
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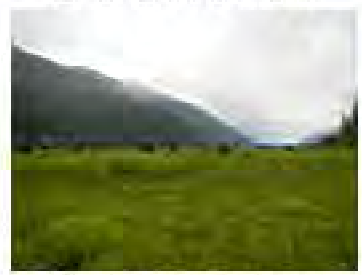
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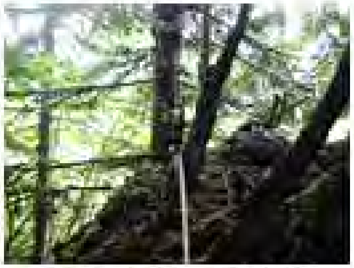
Duncan Reservoir 2018_Site 13 Transect 720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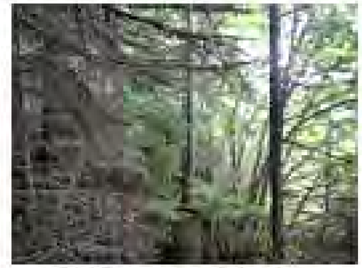
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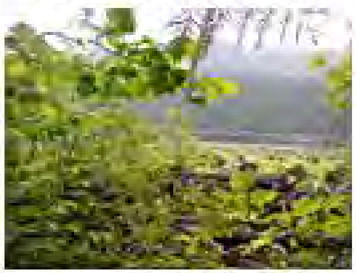
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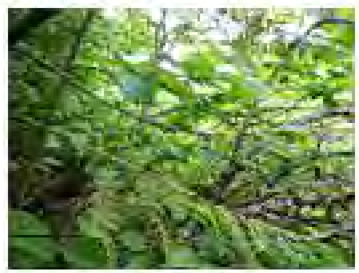
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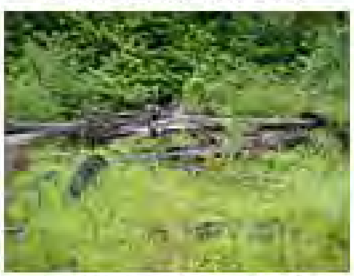
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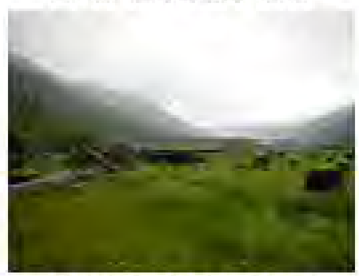
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Duncan Reservoir 2018_Site 13 Transect 720


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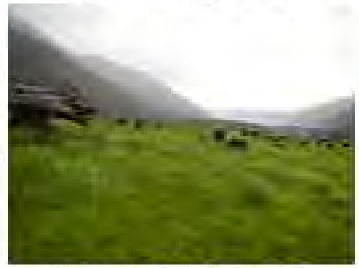
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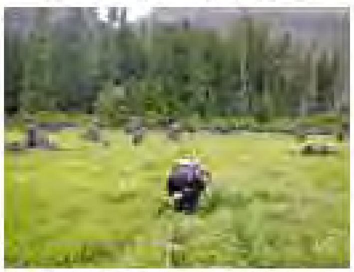
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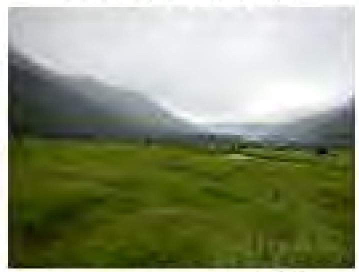
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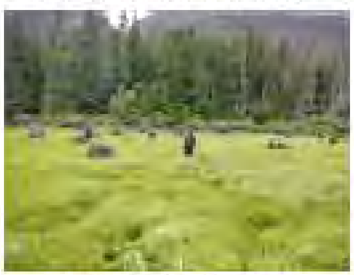
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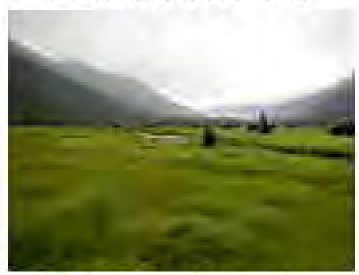
DSCN6782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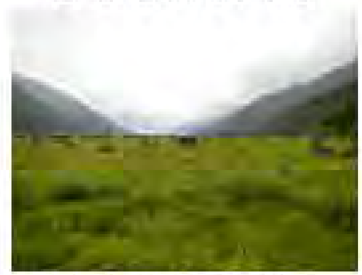
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